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WASTE COMPOSITION STUDIES

Bureau of Solid Waste Disposal
Department of Environmental Quality Engineering
Commonwealth of Massachusetts

MARCH 1986

WASTE COMPOSITION STUDIES:

LITERATURE REVIEW AND PROTOCOL

October, 1985

By Frederick W. McCamic
For Ferrand and Scheinberg Associates

Under Contract to:

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BUREAU OF SOLID WASTE DISPOSAL

John Schall, Recycling Director

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CHAPTER 1 INTRODUCTION

The State of Massachusetts, Bureau of Solid Waste Disposal has been engaged in planning for the initiation of a statewide recycling program, with the goal of recovering 15% of residential solid waste in the State and 25% of all solid waste. The program is expected to feature curbside collection of mixed recyclables, and processing at "Material Recovery Facilities" (MRF's).

Ferrand and Scheinberg Associates, under contract to the Bureau, has provided services supportive of the Bureau's recycling planning. This report is provided under Ferrand and Scheinberg Associates contract to the Bureau.

This paper reviews a variety of reports which have characterized waste streams, in order to glean findings that may be pertinent to the Bureau's planning, and to describe the methods of research that have been used.

In part, the objective has been to find reasonable numbers to use for estimates of recyclable generation in the waste stream. In response to this objective, persons contacted to obtain reports, and the reports themselves, have joined to warn that waste generation numbers are unique to their time and place. "Do not try to import numbers from some other place; you need to do your own study if you want to have reliable numbers."

For those willing to ignore the foregoing advice, Chapter 2, Results, reproduces representative numbers. In particular Table 3 compares percentage composition from a number of studies by imposing a common classification scheme on them. Table 2 hints at the difficulty of creating Table 3 by displaying the variety of classification schemes. The usefulness of percentage composition data is compromised not only by a hodge-podge of classifications, but by the see-saw effect of greater or lesser amounts of one material on the percentage of another. Yard waste, for example, may account for 5% or 20%. The same absolute amount of other material will be a greater or lesser percent of the total, depending on which situation exists.

It is for this reason that Tables 4 through 8 may be more to the point for recyclers. These tables display per capita generation rates of materials on a per day and annual basis. Not only do these tables display per capita rates, but the classification uses categories that are reasonably meaningful for recyclers. This means, for example, that beer and soft drink containers are distinguished as one species of glass, in contrast to some reports at the other extreme which have reported the overly broad "glass and ceramics." The combination of meaningful categories, and per capita rates is all too rare among the studies reviewed.

The balance of Chapter 2 is devoted to a range of qualitative findings on such matters as the effects of season, income levels, and so forth, on waste generation and composition,

and the participation in and recovery rates experienced by several recycling programs.

Chapter 3, Protocols, is devoted to a review of the methods of research that were used to acquire the results discussed in Chapter 2. As an opening proposition, Chapter 3 suggests that research methods are largely dictated by the purpose of the research and the budget available.

Since most research involves sampling, several statistical considerations are discussed. In addition to technically sound sampling, it is also noted that a research team must be alert and generally have their noses to the grindstone--more than one study has noted problems that were attributable to what may charitably be called goofs. While we are here concerned primarily with waste composition, we note that the amount of waste generated and disposed of is also at issue, and there is no real substitute for permanent scales at landfills and transfer stations.

The protocols reviewed, studies which relied on literature aside, may be classed into one of three general categories: 1) Sampling at the point of disposal, 2) sampling at the source, 3) modelling.

Sampling at the point of disposal appears to be a favored method, probably because it is the chosen means of studying waste streams when a "Resource Recovery" or "Waste to Energy" facility is being designed. If done carefully, such a study should fairly characterize the waste stream arriving at the landfill or transfer station. The recycler, given the opportunity to influence the conduct of the study, should first seek to ensure that the classification scheme provides useful information on separable materials. Next, the recycler should also ensure that thorough research is done on the sources of waste, including the land uses and demographics of the waste shed.

Sampling at the source has most often been initiated by researchers whose interest is in recycling. The objective has sometimes been to derive per capita waste generation rates, and sometimes to study behavior--how many people participate in a recycling program or what fraction of recyclable waste is successfully separated?

Modelling is perhaps not research at all, except where it is subject to validation. It must be examined, however, because it so often appears in documents in the form of desktop assessments that make use of generation factors applied to population. The factors applied are in turn very often drawn from the Fourth Report to Congress on Resource Recovery and Waste Reduction, which draws its generation rates for various materials from a "product-materials flow analysis." This analysis looks at the material composition of products, the amount of the product sold and the life expectancy of the product, and predicts the amount and composition of waste on that basis. In fairness, the results are adjusted to some control totals. This approach allows the

inquisitive recycler to ask such questions as "What would be the implications if plastic soft drink containers captured 80% of the market?"

The chapter concludes with recommendations regarding field studies. It is suggested that sampling and sorting at the point of disposal is appropriate for characterizing the entire waste stream. Recycling planners should ensure that such studies use a classification scheme that provides them with the information they need, and that adequate documentation regarding the waste shed is provided. For studies of recycling program effectiveness, it is suggested that census tracts or block groups be the unit of analysis, and that all of the waste and recyclables generated within selected tracts or block groups be collected and characterized.

Chapter 4, How to Obtain and Use Demographic Data, looks at sources of demographic and related data. This data may be pertinent in forming expectations of the amount and composition of waste generated, and also in predicting the relative success of a recycling program.

Information of interest to the student of waste and recycling includes total population, income, type of housing--especially rental apartments as opposed to single family owner occupied homes--and some indication of land use. Population provides a base for any further calculation; income and type of housing are important indicators of the probable success of residential source separation programs. Land use may directly indicate waste generation, as in the case of commercial areas or industry, or it may simply be a further factor in affecting residential waste generation and recycling participation.

CHAPTER 2 RESULTS

2.1 Notes on the Purposes of Studies Reviewed

The studies reviewed have had various purposes, and the methods and results have been tailored to the specific purposes at hand.

2.1.1 Comprehensive Waste Management Planning

Many of the existing studies reviewed are solid waste management plans for counties or regions, with waste composition being only a part of the entire study. Such reports deal with subject matter ranging from waste generation and composition, to waste flows, landfill capacity, management options, and capital costs. Composition data often is at a rather general level, for example, classing "glass and ceramics" together. Some comprehensive plans devote a chapter to source separation and recycling, but typically rely for composition data on previously published reports, such as EPA's Fourth Report to Congress: Resource Recovery and Waste Reduction.

2.1.2 Resource Recovery Plant Planning

There is a moderately large number of reports prepared for the purpose of planning and designing waste to energy facilities. While the technology is only beginning to be used on a wide scale, the large capital cost of each plant virtually ensures that a waste generation and composition study will be an integral part of the planning for each plant.

Studies done for the purpose of resource recovery plant planning generally include a waste stream inventory, i.e. quantities and sources, an analysis of composition by material, and a laboratory analysis to determine the fuel characteristics of the waste. Waste composition is generally determined through sampling of the waste stream as delivered to landfills or transfer stations.

Composition data generated in these reports is often of a general nature; glass is rarely further classified into beverage/non-beverage or by color; paper may or may not be further classified. If further classification is performed, it generally includes broad material categories such as ferrous/non-ferrous, but rarely assesses the potential for recovery through source separation. Per capita generation rates are often omitted, or are calculated on the basis of residential and commercial combined waste per capita for a region. These studies, while adequate for resource recovery design, fall short of providing the information needed for recycling planning.

2.1.3 Recycling Recovery Potential

Perhaps the majority of reports assessing the potential for material recovery and waste reduction through source separation and recycling are desktop assessments. Desktop assessments make use of generation and composition data from prior reports, coupled with extensive assumptions about participation and recovery. Part of the necessity of desktop assessments stems from limited budgets available for recycling compared to the large expenditures for resource recovery.

Fortunately, several studies have been done to assess the amount of household waste generation, the amount of material recovered through existing recycling programs, and the amount of recoverable material remaining in the refuse stream. These studies tend to include collection from generators, generally households, rather than sampling at the disposal site, and involve hand sorting into categories that are meaningful for the purpose of assessing the potential for separation.

A study of Marblehead and Somerville, Massachusetts collected household refuse, and examined the amount and nature of separated and refuse material, and compared the participation and recovery rates in the two towns. The Milwaukee Garbage Project examined household waste composition in detail, including comparisons of consumption patterns between neighborhoods of different incomes. A study in Toronto examined the potential for targeting of collection routes and materials picked up in order to maximize the revenue to cost ratio.

2.2 Waste Generation and Composition

2.2.1 Generation

Per capita waste generation rates reported in published sources vary widely. Most often, published generation rates are for combined residential and commercial waste, often referred to as "municipal solid waste" or "MSW". When MSW generation is reported, it generally includes yard waste and "oversize and bulky waste" such as discarded appliances and tires.

Reported MSW generation ranges from about 2.3 lb/capita/day to 2,400 lb/capita/year (6.58 lb/cap/day), with the majority of values in the range of 2.5 to 4 lb/cap/day. Where residential waste can be separately identified, it ranges from about 1.4 to 2.8 lb/cap/day. One report, the Milwaukee Garbage Project [1], suggests that residential generation may be lower than commonly published figures. While a per capita rate is not stated in the report, a derivation based on information in the report suggests a rate of about .93 to 1.65 lb/cap/day.[2] The Milwaukee study did not account for oversize or yard waste.

Estimates of residential waste generation in the range of 1.4 to 2.8 lb/cap/day appear to be credible.

Per capita solid waste generation rates as reported in a number of the studies reviewed are presented in the following table. Where residential and commercial waste have been reported separately, they are presented in the first two columns. The third column presents combined residential and commercial waste, or "Municipal Solid Waste" (MSW). The fourth column presents a total that includes industrial waste.

Table 1: Representative Per Capita Solid Waste Generation Rates

Report	Res	Com	R+C	Total
NEMCOG	2.9	1.3	4.2	6.3
Ann Arbor	1.85		4.32	
Ingham County	1.63	.23	2.3	
Conn (EPA)			4.0	
Dover Del			2.47	
Delaware				
Low			2.41	
High			6.58	
Lincoln Co Me.	2.88			
Nottingham NH	2.1			
Portland Ore				4.20
Rutland	2.1			3.74
Sullivan, Windsor, Windham Co				3.68
United States (Franklin)			3.47	

Note: "Res"=Residential, "Com"=Commercial, "R+C"=Residential and Commercial combined, often referred to as "Municipal Solid Waste"or MSW. "Total" indicates a total that may also include other sources of waste including industrial. The reports reviewed did not always make these distinctions clear.

2.2.2 Factors Affecting Waste Generation Rates

Generation rates of solid waste have been observed to vary greatly from time to time and location to location. Among the factors accounting for variation are the total population of the area, degree of urbanization, season of the year, income level of the neighborhood, and the state of the economy.

Size of Place

A desktop study of materials recovery in Vermont and New Hampshire assumed that generation was 2.4 lb/cap/day in communities of less than 4,500 persons, 2.8 lb/cap/day in communities larger than 4,500. [3]

The Dane County (Wisconsin) Solid Waste Plan found that generation rates were lower in rural areas than in urban areas.

For calculation of overall county generation rates, the Dane county planners assumed that generation rates were: 2.2 lb/cap/day in urban areas of 10,000 or more; 1.6 lb/cap/day in villages of 2,500-10,000; 1.00 lb/cap/day in rural areas with incorporated places; .85 lb/cap/day in very rural areas with one or fewer incorporated places of 1,000 or less. [4]

A Delaware study using landfill records found annual waste generation of 880 lb/cap/year (2.4 lb/cap/day) in rural areas, 2,400 lb/cap/year (6.6 lb/cap/day) in wealthy coastal areas. [5]

Season

A study of waste generation in the Portland area found that total waste generation could vary seasonally from 80 to 120 percent of the average monthly rate for the entire year. [6] Seasonal recreational population may cause extensive seasonal variation. For example, the Delaware study reported waste generation by transient population in coastal recreational areas at 370 lb/cap/year [7] Another Delaware study found that yard waste was at a peak in the fall. [8] Ingham County (Michigan) found extensive seasonality in waste generation. [9]

Much seasonality may be due to varying use of produce, seasonal variation in yard waste, and "spring cleaning." By contrast, domestic packaging and newspaper may vary less.

Income Level and the State of the Economy

Both income and the state of the economy have been found to affect the rate of waste generation. The Milwaukee Garbage Project, while noting that income levels can not be used in a simple way to explain waste generation, reported that lower income households appear to generate more household refuse than middle or upper income households. This was attributed to different consumption patterns which resulted in the use of more packaging. [10] The Dane County SWM Plan noted a correlation between the rate of increase of the GNP and per capita solid waste generation rates. [11] In Wastepaper: The Future of a Resource, Franklin Associates found an increase in per capita waste generation with time, and has projected continuing increases. Nationwide, Franklin Associates estimated combined residential and commercial waste generation at 3.29 lb/cap/day in 1971, 3.47 lb/cap/day in 1980, and projected that it would rise to 3.66 lb/cap/day by 1990. [12]

2.2.3 Composition

The most useful information for planning for material recovery through source separation would appear to be generation rates in pounds per capita per day or pounds per capita per year for each type of recoverable material. In addition to a material classification, a product classification would be helpful. This would include, for example, a further classification of glass into container glass and non-container glass, or even non-

beverage container glass. In Massachussetts, which is a deposit law state, it is of interest to know what fraction of glass is non-beverage and therefore non-deposit container glass for example.

Much of the composition data that is reported uses categories that do not make the pertinent fractions of the waste stream easily identifiable. Glass, for example, may be reported as "glass", or worse yet "glass and ceramics". It is difficult to compare different sources of data because categories often differ. It seems that there is no single accepted classification scheme for composition studies. Representative classification schemes are summarized in Table 2, below.

Table 2: Classification Schemes for Solid Waste Composition Reports

The Waste Disposal in New York City (Nationwide, per Franklin Associates) [13]	Connecticut Source Separation (Adaptation of Fourth Report to Congress) [14]	Tichenor: Economics of Small Rural Town Recycling [15]
Paper	Paper	Newspaper
Glass & Ceramics	Newspaper	Cardboard
Metals	Books & Magazines	Mixed paper
Ferrous	Office Paper	Glass
Aluminum	Corrugated	Cans
Other non-ferrous	Glass Containers	Total Recycled
Textiles	Metal	Rubbish
Rubber & Leather	Ferrous-Appliances	Total
Plastics	Ferrous Cans	
Wood	Ferrous-other	
Food & Yard	Non ferrous	
Misc including bricks, rock & dirt	Aluminum	
	All else	

Table 2: Classification Schemes for Solid Waste Composition Reports (cont.)

Tichenor: Economic Analysis of Recycling/ Incineration Systems Lincoln Co, Me [16]	SCS For Essex, Hudson, Hudson, Union Counties and RAS for Passaic County (New Jersey) [17],[18]	NEMCOG Ann Arbor Ingham County (Michigan) [19],[20],[21]
Newspaper	Newspaper	Paper
Mixed Paper	Corrugated	Newsprint
Corrugated Cardboard		Corrugated
Scrap Iron	Ferrous	Office
Tin Cans	Aluminum	Other paper
Aluminum		
Glass	Glass	Plastic
Incinerator Material		Returnable
	Plastic	Non-returnable
	Organics	Wood
	Wood	
		Yard waste
	Fines	
	Misc.	Textiles
		Food waste
		Rubber
		Misc organics
		TOTAL COMBUSTIBLES
		Glass
		Returnable
		Non-returnable
		Ferrous
		Returnable
		Non-returnable
		Aluminum
		Returnable
		Non-returnable
		Other non-ferrous
		Misc inorganic
		TOTAL NON-COMBUSTIBLE
		GRAND TOTAL

Table 2: Classification Schemes for Solid Waste Composition Reports (cont.)

Portland Metro [22]	Waste Generation in California [23]	Solid Waste Resources from the Fresno-Clovis Metro Area [24]
Newsprint	Paper	Paper
Corrugated	Newspaper	Newspaper
Ferrous Metal	Corrugated	Corrugated
Light Organics	Mixed	Mixed
Heavy Organics	Metals	Metals
Misc Inorganics	Ferrous	Ferrous
	Non-Ferrous	Non-Ferrous
	Organics	Organics
	Plastic	Plastic
	Yard and Tree	Yard and Tree
	Other	Other
	Inorganics	Inorganics
	Glass	
	Other	

Categories that are appropriate for resource recovery plant design, in particular, may be of limited usefulness in assessing recycling potential. Relatively broad categories may not only obscure the particular components of greatest interest, such as container glass, tin cans, and newsprint, but in some cases the very important yard waste category may be obscured in an "other organic" category. Yard waste tends to comprise about 18% of MSW, but is highly variable, ranging from a few percent to 45%. The absolute amount of other materials may remain constant but the percentage of the total waste stream that they represent may be greatly affected by the inclusion or exclusion of yard waste.

Most studies address the percentage composition of the combined residential and commercial waste stream, though a few isolate purely residential waste. Frequently, composition is reported for total MSW only, and residential and commercial waste quantities are expressed as a percentage of the total. Since commercial and residential composition is likely to differ, it is impossible to derive the composition of residential waste only.

Industrial waste is generally dealt with separately, for several reasons. Industrial waste tends to be uniform in composition, and very different from MSW, with the composition dependent on the particular industry. While important in an overall recycling strategy, industrial waste is not addressed in this study.

The following table compares percentage composition of solid

waste from a number of studies. A consistent classification system has been used in order to facilitate comparisons. Categories which were not reported in a particular study, or which are indeterminate due to inconsistencies in reporting have been indicated with a dash (-) in the table.

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources.

New Castle County: Update August 1978 [25]

	Bureau of Mines Test Dry Weight	USEPA 4th Report to Congress 1977
Newspaper	-	-
Corrugated	-	-
Mixed Paper	-	-
Total Paper	50.5	31.6
Ferrous Cans	-	-
Misc Ferrous	-	-
Ferrous Total	9.3	9.9
Aluminum Cans	-	-
Misc Aluminum	0.8	0.8
Other Non-Ferrous	0.2	0.4
Non-Ferrous Total	1.0	1.2
Total Metals	10.3	11.1
Glass Containers	-	-
Misc Glass	-	-
Total Glass	12.7	12.1
Tot Glass & Ceramics	-	-
Plastic	5.8	4.0
Yard Waste	3.4	17.5
Food Waste	0.9	15.4
Wood	3.0	3.3
Textiles	2.6	1.5
Organics N.E.C.	2.4	2.2
InOrganics N.E.C.	-	-
All Else N.E.C.	8.4	1.3
Total	100.0	100.0

Note: N.E.C="Not Elsewhere Classified"

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Central Wayne County, Michigan [26]

	Adjusted For Moisture Loss	Excluding Yard Waste
Newspaper	8.09	13.40
Corrugated	-	-
Mixed Paper	23.90	39.50
Total Paper	31.99	52.90
Ferrous Cans	-	-
Misc Ferrous	-	-
Ferrous Total	3.06	5.05
Aluminum Cans	-	-
Misc Aluminum	0.26	0.42
Other Non-Ferrous	0.47	0.78
Non-Ferrous Total	0.73	1.20
Total Metals	3.79	6.25
Glass Containers	-	-
Misc Glass	-	-
Total Glass	3.32	5.48
Tot Glass & Ceramics	-	-
Plastic	5.37	8.88
Yard Waste	39.40	excluded
Food Waste	3.33	5.50
Wood	1.15	1.89
Textiles	4.01	6.62
Organics N.E.C.	-	-
InOrganics N.E.C.	4.19	6.91
All Else N.E.C.	3.43	5.64
Total	100.00	100.00

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Three Waste Composition Studies in Michigan

	Ann Arbor[27]	Ingham County[28]	Northeast Michigan Council of Governments[29]
Newspaper	5.90	11.93	5.20
Corrugated	7.47	4.74	11.20
Mixed Paper	24.58	28.74	28.40
Total Paper	37.95	45.41	44.80
Ferrous Cans	-	-	-
Misc Ferrous	5.43	3.69	6.60
Ferrous Total	5.43	3.69	6.60
Aluminum Cans	-	-	-
Misc Aluminum	1.01	1.32	0.83
Other Non-Ferrous	-	1.43	0.50
Non-Ferrous Total	1.01	2.75	1.33
Total Metals	6.44	6.44	7.93
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	3.08	6.28	5.33
Tot Glass & Ceramics	-	-	-
Plastic	5.75	6.85	9.20
Yard Waste	10.84	12.78	4.10
Food Waste	4.08	8.50	11.50
Wood	5.36	2.87	3.50
Textiles	6.40	6.30	4.20
Organics N.E.C.	7.28	1.47	5.20
InOrganics N.E.C.	13.09	3.07	4.30
All Else N.E.C.	-	-	-
Total	100.00	100.00	100.00

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

	Portland Metro [30]			
	Rossmans		St. John's	
	Res	Com	Res	Com
Newspaper	8.1	5.9	10.3	2.9
Corrugated	5.1	10.5	3.9	11.9
Mixed Paper	-	-	-	-
Total Paper	-	-	-	-
Ferrous Cans	-	-	-	-
Misc Ferrous	-	-	-	-
Ferrous Total	6.6	5.7	7.1	3.1
Aluminum Cans	-	-	-	-
Misc Aluminum	-	-	-	-
Other Non-Ferrous	-	-	-	-
Non-Ferrous Total	0.0	0.0	0.0	0.0
Total Metals	0.0	0.0	0.0	0.0
Glass Containers	-	-	-	-
Misc Glass	-	-	-	-
Total Glass	0.0	0.0	0.0	0.0
Tot Glass & Ceramics	-	-	-	-
Plastic	-	-	-	-
Yard Waste	-	-	-	-
Food Waste	-	-	-	-
Wood	-	-	-	-
Textiles	-	-	-	-
Organics N.E.C.	73.9	74.0	71.8	78.9
InOrganics N.E.C.	6.3	3.9	6.9	3.2
All Else N.E.C.	-	-	-	-
Total	100.0	100.0	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Atlantic County, New Jersey [31]

	Residential	Commercial	Total
Newspaper	12.9	6.8	9.1
Corrugated	2.9	11.6	8.2
Mixed Paper	19.5	25.1	22.9
Total Paper	35.3	43.5	40.2
Ferrous Cans	-	-	-
Misc Ferrous	-	-	-
Ferrous Total	5.0	5.7	5.4
Aluminum Cans	-	-	-
Misc Aluminum	-	-	-
Other Non-Ferrous	-	-	-
Non-Ferrous Total	2.0	1.8	1.8
Total Metals	7.0	7.5	7.2
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	10.7	10.8	10.7
Tot Glass & Ceramics	-	-	-
Plastic	7.3	9.3	8.5
Yard Waste	8.5	1.4	4.0
Food Waste	-	-	-
Wood	-	-	-
Textiles	6.0	3.1	4.2
Organics N.E.C.	18.0	16.3	17.1
InOrganics N.E.C.	0.8	1.3	1.1
All Else N.E.C.	6.6	6.5	6.5
Total	100.0	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Essex, Hudson, and Union Counties, New Jersey [32]

	Residential	Commercial	Combined
Newspaper	6.27	2.96	5.23
Corrugated	11.60	23.21	15.23
Mixed Paper	-	-	-
Total Paper	-	-	-
Ferrous Cans	-	-	-
Misc Ferrous	-	-	-
Ferrous Total	6.33	6.96	6.53
Aluminum Cans	-	-	-
Misc Aluminum	1.36	0.74	1.17
Other Non-Ferrous	-	-	-
Non-Ferrous Total	-	-	-
Total Metals	-	-	-
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	9.02	3.63	7.33
Tot Glass & Ceramics	-	-	-
Plastic	6.24	4.35	5.65
Yard Waste	-	-	-
Food Waste	-	-	-
Wood	2.34	10.31	4.83
Textiles	-	-	-
Organics N.E.C.	38.08	35.25	37.19
InOrganics N.E.C.	-	-	-
All Else N.E.C.	18.64	12.56	16.73
Total	100.00	100.00	100.00

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Waste Generation and Disposal in California, 1982 [33]

	North	Bay Area	Central
Newspaper	6.7	8.8	7.5
Corrugated	6.8	6.5	10.1
Mixed Paper	26.5	32.5	32.2
Total Paper	40.0	47.8	49.8
Ferrous Cans	-	-	-
Misc Ferrous	-	-	-
Ferrous Total	8.0	5.1	6.1
Aluminum Cans	-	-	-
Misc Aluminum	-	-	-
Other Non-Ferrous	-	-	-
Non-Ferrous Total	2.0	0.9	2.1
Total Metals	10.0	6.0	8.2
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	8.0	8.1	6.3
Tot Glass & Ceramics	-	-	-
Plastic	2.5	4.0	6.2
Yard Waste	3.0	13.9	12.1
Food Waste	-	-	-
Wood	-	-	-
Textiles	-	-	-
Organics N.E.C.	26.5	16.3	16.1
InOrganics N.E.C.	10.0	3.9	1.3
All Else N.E.C.	-	-	-
Total	100.0	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Waste Generation and Disposal in California, 1982 (Cont.)

	L.A. Basin	Sierra East	South
Newspaper	8.0	6.7	8.0
Corrugated	8.3	6.8	8.3
Mixed Paper	32.4	26.5	32.4
Total Paper	48.7	40.0	48.7
Ferrous Cans	-	-	-
Misc Ferrous	-	-	-
Ferrous Total	5.6	8.0	5.6
Aluminum Cans	-	-	-
Misc Aluminum	-	-	-
Other Non-Ferrous	-	-	-
Non-Ferrous Total	1.5	2.0	1.5
Total Metals	7.1	10.0	7.1
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	7.2	8.0	7.2
Tot Glass & Ceramics	-	-	-
Plastic	5.3	2.5	5.3
Yard Waste	17.1	3.0	17.1
Food Waste	-	-	-
Wood	-	-	-
Textiles	-	-	-
Organics N.E.C.	12.0	26.5	12.0
InOrganics N.E.C.	2.6	10.0	2.6
All Else N.E.C.	-	-	-
Total	100.0	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Study of Solid Waste Composition
in Passaic Co., NJ, August 1982 [34]

	Municipal	Commercial	Industrial	Total Average
Newspaper	11.4	12.4	17.9	13.7
Corrugated	17.5	37.1	33.4	29.3
Mixed Paper	-	-	-	-
Total Paper	-	-	-	-
Ferrous Cans	-	-	-	-
Misc Ferrous	-	-	-	-
Ferrous Total	2.3	2.9	2.8	2.7
Aluminum Cans	-	-	-	-
Misc Aluminum	1.6	4.0e-02	2.6	1.5
Other Non-Ferrous	-	-	-	-
Non-Ferrous Total	-	-	-	-
Total Metals	2.3	2.9	2.8	2.7
Glass Containers	-	-	-	-
Misc Glass	-	-	-	-
Total Glass	9.2	1.8	3.8	0.0
Tot Glass & Ceramics	-	-	-	-
Plastic	8.3	9.8	8.2	8.8
Yard Waste	-	-	-	-
Food Waste	-	-	-	-
Wood	2.8	7.5	17.0	9.2
Textiles	-	-	-	-
Organics N.E.C.	-	-	-	-
InOrganics N.E.C.	-	-	-	-
All Else N.E.C.	46.9	28.1	18.1	31.0
Total	100.0	100.0	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Marblehead and Somerville, Massachusetts [35]

	Marblehead 4 Seasons	Somerville Fall, Spring, Summer
Newspaper	15.1	9.5
Corrugated	1.5	0.9
Mixed Paper	22.1	20.5
Total Paper	38.7	30.9
Ferrous Cans	-	-
Misc Ferrous	-	-
Ferrous Total	4.3	6.2
Aluminum Cans	-	-
Misc Aluminum	-	-
Other Non-Ferrous	-	-
Non-Ferrous Total	0.6	0.8
Total Metals	4.9	7.0
Glass Containers	-	-
Misc Glass	-	-
Total Glass	17.6	19.1
Tot Glass & Ceramics	-	-
Plastic	-	-
Yard Waste	-	-
Food Waste	-	-
Wood	-	-
Textiles	-	-
Organics N.E.C.	-	-
InOrganics N.E.C.	-	-
All Else N.E.C.	39.7	43.6
Total	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

The Milwaukee Garbage Project [36]

	Middle Income 1	Middle Income 2	Medium Low Income
Newspaper	15.24	8.68	15.37
Corrugated	-	-	-
Mixed Paper	23.25	21.57	20.07
Total Paper	38.49	30.25	35.44
Ferrous Cans	-	-	-
Misc Ferrous	7.18	7.06	5.91
Ferrous Total	7.18	7.06	5.91
Aluminum Cans	-	-	-
Misc Aluminum	1.14	0.96	1.30
Other Non-Ferrous	0.16	0.26	0.26
Non-Ferrous Total	1.30	1.22	1.56
Total Metals	8.48	8.28	7.47
Glass Containers	-	-	-
Misc Glass	-	-	-
Total Glass	7.62	9.95	11.62
Tot Glass & Ceramics	-	-	-
Plastic	7.11	5.44	4.19
Yard Waste	8.76	16.01	12.72
Food Waste	23.41	24.60	21.67
Wood	-	-	-
Textiles	1.30	1.49	1.73
Organics N.E.C.	-	-	-
InOrganics N.E.C.	-	-	-
All Else N.E.C.	4.83	3.55	5.66
Total	100.00	99.57	100.50
lb/HH/week	25.46	22.80	23.16

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

The Milwaukee Garbage Project (Cont.)

	Low Income 1	Low Income 2
Newspaper	11.94	13.61
Corrugated	-	-
Mixed Paper	23.64	22.81
Total Paper	35.58	36.42
Ferrous Cans	-	-
Misc Ferrous	8.11	7.07
Ferrous Total	8.11	7.07
Aluminum Cans	-	-
Misc Aluminum	1.48	2.26
Other Non-Ferrous	0.00	0.10
Non-Ferrous Total	1.48	2.36
Total Metals	9.59	9.43
Glass Containers	-	-
Misc Glass	-	-
Total Glass	19.08	7.78
Tot Glass & Ceramics	-	-
Plastic	5.47	6.35
Yard Waste	1.52	8.16
Food Waste	21.10	18.23
Wood	-	-
Textiles	3.00	5.76
Organics N.E.C.	-	-
InOrganics N.E.C.	-	-
All Else N.E.C.	4.67	7.81
Total	100.00	100.00
lb/HH/week	27.63	28.80

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Fresno-Clovis Metropolitan Area [37]

	Fresno-Clovis Metro Area	National Average Smith,F.L. USEPA
Newspaper	8.5	6.0
Corrugated	9.4	9.0
Mixed Paper	30.4	18.0
Total Paper	48.3	33.0
Ferrous Cans	-	-
Misc Ferrous	-	-
Ferrous Total	5.8	8.2
Aluminum Cans	-	-
Misc Aluminum	-	-
Other Non-Ferrous	-	-
Non-Ferrous Total	1.9	1.0
Total Metals	7.7	9.2
Glass Containers	-	-
Misc Glass	-	-
Total Glass	5.9	9.9
Tot Glass & Ceramics	-	-
Plastic	5.9	-
Yard Waste	12.9	18.5
Food Waste	-	16.6
Wood	-	-
Textiles	2.9	-
Organics N.E.C.	15.2	-
InOrganics N.E.C.	1.9	-
All Else N.E.C.	-	12.8
Total	100.0	100.0

Table 3: Comparison of Percentage Composition of Solid Waste as Reported by Several Sources (cont.)

Municipal Waste Composition per Unpublished Update to EPA 4th Report to Congress on Resource Recovery and Waste Reduction[38]

Material	Percent
Newspaper	7.3
Corrugated	9.8
Mixed Paper	17.7
Total Paper	34.8
Ferrous Cans	2.0
Misc Ferrous	-
Ferrous Total	-
Aluminum Cans	0.6
Misc Aluminum	-
Other Non-Ferrous	-
Non-Ferrous Total	-
Total Metals	-
Glass Containers	8.9
Misc Glass	-
Total Glass	-
Tot Glass & Ceramics	-
Plastic	-
Yard Waste	17.6
Food Waste	15.4
Wood	-
Textiles	-
Organics N.E.C.	-
InOrganics N.E.C.	-
All Else N.E.C.	20.7
Total	100.0

2.2.4 Per Capita Generation Rate of Source Separable Materials

A few studies have either collected data on per capita generation of particular materials, or have manipulated data so as to express results in that form. Manipulation is possible if both a per capita generation rate and a percentage composition are available. It is a matter of simple arithmetic to multiply the composition by the generation rate. What is crucial to obtaining a valid result is to first ensure that the per capita rate and composition data refer to the same waste stream. Where data from different sources are mixed, there is no assurance that the results will be valid.

Per capita generation rates for various materials are presented in the following five tables. For each table, the report that was the source of the composition data either presented the per-capita generation rate, or at least made it clear that the composition and total generation data referred to the same waste stream. These tables represent the results of three different study methods, including 1) product/materials flow analysis, 2) sample and sort at the point of disposal, 3) delivery of separated recyclables to a small town recycling center by individual households.

Table 4, immediately below, presents material generation rates for the nation, estimated from a product/material flow analysis, adjusted to a control total. Tables 5 through 7, from Michigan, are the result of sample and sort studies at landfills, combined with landfill records of total waste. Table 8, from Nottingham NH, was generated by weighing individual household waste delivered to a small town recycling center.

Table 4: Material Generation in Municipal Solid Waste per Unpublished Updated Data for EPA Report to Congress on Resource Recovery and Waste Reduction [39]

	Percent	Pounds Per Capita Per Day	Pounds Per Capita Per Year
Paper			
Newspaper	7.3	0.27	101.5
Books & Magazines	4.7	0.18	66.2
Office Paper	3.4	0.12	47.3
Corrugated	9.8	0.37	136.0
Mixed Paper	9.4	0.35	130.1
Total Paper	34.8	1.31	481.2
Ferrous Containers			
Beer & Soft Drink	0.3	0.01	4.7
Food Cans	1.3	0.05	18.5
Other Nonfood Cans	0.4	0.01	6.7
Barrels, Drums, etc.	0.1	5.96e-03	2.1
Ferrous Container Total	2.3	0.08	32.1
Aluminum Containers			
Beer & Soft Drink	0.6	0.02	8.3
Other Cans	2.3e-02	8.76e-04	0.3
Foil	0.2	7.71e-03	2.8
Aluminum Container Total	0.8	0.03	11.4
Glass Containers			
Beer & Soft Drink	4.4	0.16	61.7
Wine & Liquor	1.5	0.05	21.8
Food and Other	2.9	0.11	40.2
Total Glass	8.9	0.33	123.8
Plastic	2.6	0.10	36.5
Subtotal Paper & Packaging	49.5	1.87	685.3
Yard Waste	17.6	0.66	244.4
Food Waste	15.4	0.58	214.1
Subtotal Food and Yard	33.1	1.25	458.5
Durable Goods: Major Appliances, Furniture, Tires Etc..	11.5	0.43	159.3
All Else	5.7	0.21	79.5
Total	100.0	3.78	1382.9

Table 5: Waste Composition and Generation in Ann Arbor, Michigan [40]

	PERCENT	LB/CAP/DAY	LB/CAP/YR
Paper			
Newsprint	5.90	0.25	93.0
Corrugated	7.47	0.32	117.7
Office	4.28	0.18	67.4
Other paper	20.30	0.87	320.0
Total paper	37.95	1.63	598.3
Plastic			
Returnable	0.05	2.16e-03	0.7
Non-returnable	5.70	0.24	89.8
Total plastic	5.75	0.24	90.6
Wood	5.36	0.23	84.5
Yard waste	10.84	0.46	170.9
Textiles	6.40	0.27	100.9
Food waste	4.08	0.17	64.3
Rubber	2.30	0.09	36.2
Misc organics	4.98	0.21	78.5
TOTAL COMBUSTIBLES	77.66	3.35	1224.5
Glass			
Returnable	0.18	7.77e-03	2.8
Non-returnable	2.90	0.12	45.7
Ferrous			
Returnable	0.27	0.01	4.2
Non-returnable	5.16	0.22	81.3
Aluminum			
Returnable	0.03	1.29e-03	0.4
Non-returnable	0.71	0.03	11.1
Other non-ferrous	N/A		
Misc inorganic	13.09	0.56	206.4
TOTAL NON-COMBUSTIBLES	22.34	0.96	352.2
GRAND TOTAL	100.00	4.32	1576.8

Table 6: Waste Composition and Generation in Ingham County, Michigan [41]

	FRACTION	LB/CAP/DAY	LB/CAP/YR
Paper			
Newsprint	0.119325	0.27	100.1
Corrugated	0.047474	0.10	39.8
Office	0.045444	0.10	38.1
Other paper	0.242027	0.55	203.1
Total paper	0.454270	1.04	381.3
Plastic			
Returnable	0.000649	1.49e-03	0.5
Non-returnable	0.067871	0.15	56.9
Total plastic	0.068520	0.15	57.5
Wood	0.028698	0.06	24.0
Yard waste	0.127800	0.29	107.2
Textiles	0.062975	0.14	52.8
Food waste	0.085000	0.19	71.3
Rubber	0.009981	0.02	8.3
Misc organics	0.004667	0.01	3.9
TOTAL COMBUSTIBLES	0.841911	1.93	706.7
Glass			
Returnable	0.002480	5.70e-03	2.0
Non-returnable	0.060321	0.13	50.6
Ferrous			
Returnable	0.000244	5.61e-04	0.2
Non-returnable	0.036733	0.08	30.8
Aluminum			
Returnable	0.000704	1.61e-03	0.5
Non-returnable	0.012536	0.02	10.5
Other non-ferrous	0.014330	0.03	12.0
Misc inorganic	0.030733	0.07	25.8
TOTAL NON-COMBUSTIBLES	0.158081	0.36	132.7
GRAND TOTAL	1.000000	2.30	839.5

Table 7: Northeast Michigan Council of Governments Combined Landfills Waste Composition and Per Capita Generation [42]

	PERCENT	LB/CAP/DAY	LB/CAP/YEAR
Paper			
Newsprint	5.20	0.21	80
Corrugated	11.20	0.47	172
Office	2.50	0.10	38
Other paper	25.90	1.08	397
Total paper	44.80	1.88	687
Plastic			
Returnable	0.00	0.00	5e-01
Non-returnable	9.20	0.38	141
Total plastic	9.20	0.38	141
Wood	3.50	0.14	54
Yard waste	4.10	0.17	63
Textiles	4.20	0.17	64
Food waste	11.50	0.48	176
Rubber	2.20	0.09	34
Misc organics	3.00	0.12	46
TOTAL COMBUSTIBLES	82.50	3.46	1,265
Glass			
Returnable	0.03	1.26e-03	9e-01
Non-returnable	5.30	0.22	81
Ferrous			
Returnable	4.00e-03	1.68e-04	5e-01
Non-returnable	6.60	0.27	101
Aluminum			
Returnable	0.03	1.26e-03	9e-01
Non-returnable	0.80	0.03	12
Other non-ferrous	0.50	0.02	8
Misc inorganic	4.30	0.18	66
TOTAL NON-COMBUSTIBLES	17.50	0.73	268
GRAND TOTAL	100.00	4.20	1,533

Northeast Michigan 1980 Solid Waste Stream Assessment, Northeast Michigan Council of Governments, Solid Waste Planning Div., 9/80

Table 8: Waste Generation and Composition in Nottingham, NH [43]

Category	Percent of Total Waste	Pounds per Capita per Day	Pounds per Capita per Year
Newspaper	11.8	0.25	91.2
Cardboard	1.9	0.04	14.6
Mixed Paper	5.7	0.12	43.8
Glass	25.5	0.54	197.1
Cans	10.8	0.23	83.9
Total Recycled	55.7	1.18	430.7
Rubbish	43.9	0.93	339.4
Total Waste	100.0	2.12	773.8

2.2.5 Factors Affecting Composition

Waste composition has been found to vary with season, with degree of urbanization, with income, with container deposit laws and recycling programs, and over time. There are important differences between residential and commercial waste streams.

Season

The greatest seasonal variation is in yard waste, which generally peaks in the fall. "Spring cleaning" has also been observed to generate bulky waste. The generation of other household waste has been found to be relatively stable. No special attention has been given to possible variations in waste composition in highly seasonal resort areas; however, it seems reasonable to expect that during peak tourist seasons there might be higher percentages of beverage containers than are found in typical household refuse.

Size of Urban Area and Income

The larger the urban area, the greater the amount of commercial waste that is likely to be included in the total MSW stream. This clearly affects the quantity of waste generation, but but also affects the composition. The Milwaukee Garbage Project found that lower income households generated more packaging and textile waste, on both an absolute and percentage basis, than middle or upper income households. Higher income households generated more newsprint and more yard waste on both absolute and percentage bases. [44]

Container Deposit Laws

Container deposit laws affect waste composition, both because containers are removed from the waste stream and because product and packaging mix may change in response to deposits. Most studies of container deposit laws have found that deposits generate a very high return rate. As a result, composition studies find very low amounts of deposit law containers in waste streams.[45],[46],[47] Tichenor, in a New Hampshire/Vermont study noted that brown glass, which was primarily beer bottles, effectively disappeared from the waste stream. [48]

Recycling Programs

Reduction of the newsprint fraction of municipal waste has been noted in areas where there are active recycling programs.[49],[50] Assessment of waste generation and material recovery in such areas will require an assessment of both the material already recycled and the remaining refuse being disposed of.

Time

With time, the amount of container waste, and in particular, the amount of plastic appears to have increased. EPA estimated that on the average .11 lb/cap/day of plastic was disposed in 1971, .17 lb/cap/day in 1980, and a rate of .20 lb/cap/day was projected for 1990. [51] The U.S. Bureau of the Census and Bureau of Industrial Economics report that the number of plastic bottles increased by 4.5% from 1982 to 1983, and project an increase of 5.6% for '83-'84, and average annual increases of 5.1% through 1989. [52] This would represent a higher rate of increase in the use of plastic than predicted by EPA.

2.3 Recycling Participation and Material Recovery Rates

2.3.1 Compatibility of Recycling and Resource Recovery

Recycling has not always viewed as entirely compatible with resource recovery. One of the major reasons for this is that paper, often comprising 35-40% of the waste stream, is coveted as fuel. Paper is estimated by Franklin Associates at 30% of the waste stream, but 50% of the energy value of the waste. However, they estimate that a "50% increase in recovery of old newspapers, corrugated, and deinking grades would mean a decrease of total solid waste of only 4 percent, and of energy in solid waste by 7 percent." This, they argue, is not a serious problem to resource recovery plant operation, but mandatory routing of waste paper to a resource recovery incinerator could constitute a serious supply problem for paper recyclers. [53]

Another statement indicating that recycling is compatible with resource recovery was expressed in a letter to the

Environmental Management Council, from R.J.Broglio of Signal Environmental Systems Inc. Broglio indicated that the removal of available recyclable paper would reduce the BTU/lb value of MSW by less than 1%. At the same time he noted that the removal of glass and metals would "reduce abrasion, minimize reflection and absorption of heat and reduce ash residue." [54]

A twofold effect of source separation on heating value was noted in a report on source separation in Somerville and Marblehead, Massachusetts. The heating value per pound is increased because non-combustibles are removed, and the total heating value available is reduced because burnable material, particularly paper, is removed. [55]

A study in Essex County New Jersey also found that recycling could reduce the needed size of a planned resource recovery incinerator, with substantial savings in capital costs and finance charges. This was due in part to the reduced volume of waste, but it was also anticipated that less pollution control equipment would be required to meet emission standards, ash handling would be simplified, and equipment would last longer because of a reduction in abrasion and wear on equipment. It was estimated that diversion of 15% of waste through removal of a portion of recyclable glass, aluminum, ferrous, newsprint, and corrugated would result in a 6% increase in BTU per pound of the remaining processible solid waste. [56]

2.3.2 Effect of Container Deposit Laws

Container deposit laws clearly have the effect of removing the bulk of the deposit containers from the waste stream. An assessment of the Oregon Bottle Bill, conducted by the State's Department of Environmental Protection, found that prior to the bottle bill, 75.9% of containers were thrown away; after the bottle bill, 6.3-11.9% were thrown away. [57] According to the Oregon Liquor Control Commission, 85% of malted beverage and soda containers are redeemed for reuse and recycling. [58]

It has been reported that Michigan experienced a 6% reduction in total solid waste quantity following introduction of beverage container deposits. [59]

2.3.3 Effect of Recycling Programs

Recycling programs have been found to reduce the total waste stream by 5 to 25%, with higher goals for waste reduction where deposits plus source separation and resource recovery are contemplated. A remarkable 40% recycling rate is reported Woodbury, New Jersey.

A Waste Reduction Plan for Portland found that 13% of the area's waste was diverted through a variety of recycling options. Recycling in Portland includes not only beverage container deposits, but an array of drop off centers, and recycling pickup service by some but not all regular trash

collectors, and recyclable purchase by individual recyclers. The combination of all of the above is estimated to result in recovery of one third of the readily recyclable materials. [60]

Table 9: Recycling Rates in the Portland Metro Region in 1979

Material	Volume Recycled	Recycling Rate
Glass Bottles	16,539	31.1%
Aluminum	4,208	51.3%
Tin Cans	683	1.3 to 1.6
White Goods	16,428	--
Newspaper	26,961	35.7 to 39.4
Corrugated	45,718	48.3 to 58.8
Office Paper	9,760	23.2

Source: Waste Reduction Plan, Metro Portland, Jan 1981

Even more ambitious goals were stated by the Portland Metro Council; it was intended to ultimately reduce residential and commercial solid waste 30 percent through the recovery of all available recyclable material, with 2/3 recovery of recyclable material by 1985. [61]

In 1982, recycling in Bellingham Washington was estimated to have diverted about 15% of the total waste stream. Recycling included buy-back centers, drop-off stations, commercial cardboard collection, and residential collection. About 69% of the recycled material was paper and cardboard, which was due in part to the presence of a ready market in the form of a Georgia Pacific paperboard mill. Based on various estimates, none considered reliable, the researchers made an avowedly "crude guess" that 32.9% of the remaining waste stream consisted of readily recyclable materials. [62]

2.3.4 Participation and Material Recovery Rates

Over 40 recycling programs in various areas of the country were surveyed in the research for the Bellingham Proposed Waste Reduction & Recycling Strategy. Participation rates were found to range from less than 20% to 95%, and waste stream diversion from negligible to 45%. Several "models" for recycling collection were identified. The so called "East Coast Model" involved a mandatory ordinance, weekly pickup of mixed recyclables, with recycling pickup on the same day as regular garbage pick-up. Participation was expected to be at least 75% due to the mandatory ordinance and the convenience of mixing recyclables and frequent pickup concurrent with garbage pickup. A voluntary program in Bellingham was found to collect 55 to 58 pounds per participating household per month. It was expected that as more households were added through a mandatory ordinance the amount collected would decline to 50 lb/HH/month, because the added households would be less committed to recycling. [63]

A comparative study of source separation and recycling in

Somerville and Marblehead, Massachusetts in 1979, found that 25% of the waste stream was diverted in Marblehead, but only 5% in Somerville. In Marblehead, a high proportion of the readily recyclable materials were source separated; for example 66.9% of the newsprint and 67.5% of clear beverage glass were separated. (The study was conducted prior to the enactment of beverage container deposits, in part to assess the potential impact of such a law on source separation programs.) In Somerville, only 16.9% of newsprint was separated, and other recyclables were separated at rates of 7% or less. [64] Recovery rates for various materials are summarized in the following table.

Table 10: Percent of Available Material Recovered in Two Recycling Programs

Material	Marblehead	Somerville
Newsprint	66.9	16.9
Magazines	44.4	1.6
Corrugated paper	6.6	7.0
Other paper	3.0	0.3
Clear glass beverage	67.5	2.2
Green glass beverage	50.7	2.4
Brown glass beverage	33.9	6.5
Other clear glass	55.4	1.7
Other green glass	61.1	2.9
Other brown glass	50.3	4.1
Ferrous beverage	43.4	2.2
Other ferrous	37.8	3.6
Nonferrous beverage	51.0	2.7
Other nonferrous	12.9	1.9

Source: Resource Planning Associates, Inc. for EPA, 1979 [65]

There were significant differences in both the nature of the communities, and recycling programs. Marblehead is a less densely settled community, with a much higher percentage of single family housing, higher income and higher median education. The recycling program had been mandatory in Marblehead since 1972, but in January 1976 a new program was instituted with extensive public education and public relations, and better collection service. Participation in the recycling program more than doubled. In Somerville, participation was voluntary, and the program was suspended during the winter due to severe weather. [66]

A 1983 survey of waste composition at the Berkeley California landfill [67] combined a study of waste composition with a survey of attitudes toward separation, reuse and recycling on the part of individuals using the landfill. The study was a precursor to setting up a composting/reuse/recycling center at a

new transfer station that would replace the old landfill. Seventy percent of the waste tonnage entering the landfill was in private vehicles such as cars and pickup trucks, and only 30% was in compactor trucks.

The researchers visually estimated the volume of waste in several categories, and interviewed vehicle drivers regarding their willingness to use composting, recycling, and reuse facilities at the planned transfer station.

It was estimated that 60-65% of the material delivered to the landfill by private vehicles could be recovered by reuse, recycling or composting. Based on the "willingness" to recycle per interviews, a recovery rate of 40-45% was predicted. Since private vehicles delivered 70% of the waste to the landfill, it was recommended that the new transfer station be designed for 25% less than current and anticipated disposal levels.

The two tables following summarize the customer profile and the predicted recovery of waste at the new transfer station.

Table 11: Berkeley Landfill Customer Profiles

Customer Profile:	% of Vehicles
Contractor/Gardener	25%
Professional Hauler	17%
Business or Property Mgr	11%
Household	37%

Table 12: Berkeley Landfill Waste Composition and Recovery Predicted by Component

Component	% of Total Volume	Predicted Recovery Rate Based on Interviews
Plant Debris	35%	55%
Refuse	34%	0%
Wood	13%	65%
Inert (If a use could be found for inert material)	6%	59%
Paper	6%	80%
Resuables	4%	72%
Metals	2%	63%
Plastic (It was noted that recycling plastic is difficult)	2%	67%
Glass	1%	72%

An epilogue to the executive summary reported the experience at the new transfer station when it opened. The basic tipping fee, which had been $2, was increased to $5. Less expensive ($2.50/cu yd) composting was available. Reuseables could be dropped off at the salvage area, and recyclables could be sold to the buyback center.

The quantity of waste actually disposed at the facility declined to about half of its prior level (400 ton/day vs 200 tons/day). This was partly due to a decline in use by out of town persons (who had delivered about 30% of the waste to the old landfill) because of the higher fee. The bulk of the decline was attributed to reuse/recycling.

CHAPTER 3 PROTOCOLS

3.1 Overview

3.1.1 Different Protocols for Different Purposes (i.e. What Question are you asking?)

Waste composition and quantity studies have used a variety of protocols. While this sometimes reflects differences of opinion regarding how to proceed, in large measure it reflects the different purposes of the studies. In other words, the question that is being asked, combined with the budget available for answers, dictates the protocol.

A study for the purpose of planning landfills will seek information on gross quantities and sources. A study for resource recovery incinerator planning will report quantities, but will also include a broad classification of waste, with particular attention to combustible and non-combustible fractions, and moisture content, and will take small sub samples for laboratory analysis to determine fuel characteristics.

When recycling is a component of the solid waste management plan, more detailed classification is needed. It becomes appropriate to relate material back to product, for example e.g. "newsprint" rather than just "paper." Knowing the source of waste in some detail is necessary for the purpose of planning collection.

Actual research on waste composition will be relatively expensive. Furthermore, incorrectly designed research may give erroneous results, which could lead to costly mistakes in facilities design. It is therefore imperative that the first step toward a composition study be a careful articulation of the research question.

3.1.2 Designing a Sampling Scheme

It is impractical to sort 100% of a waste stream in order to study its composition. Sampling is necessary and appropriate for estimating waste composition.

Sampling is the process of obtaining a "representative" subset of the entire quantity of waste, so that results of studying the sample may be generalized to the whole. This process will require several steps, beginning with defining the sampling universe, then selecting samples which are "representative", ensuring that a large enough number of samples is selected to provide acceptable statistical reliability, and ensuring that the classification of the waste is both useful and valid.

3.1.3 The Sampling Universe

The sampling universe is the total or entire population of items from which samples will be drawn. When conclusions are drawn, they will apply only to the sampling universe. While this would seem obvious, it is an easy pitfall for a researcher to fall into, to say "this is so" regarding a larger universe that differs from that sampled. It is also possible that conclusions regarding the universe may not apply to subsets of the population.

Highly likely problems of sample universe definition in waste studies are:

1) There may be confusion regarding residential and commercial waste. In some cases this may be due to planners' efforts to draw conclusions about residential waste even though it was known that the original sample included both residential and commercial waste. It is also possible that the problem may be undetected, for example, it has been reported that it is common for haulers in some areas to piggyback some commercial collection on top of a largely residential collection. A surveyed driver might nonetheless assert that the route was all residential.

2) Waste shed definition can be difficult. In some rural areas, landfill access is not tightly controlled, and individuals may enter the site to dispose of household waste. In urban areas haulers may cross institutionally defined wasteshed boundaries. In either case, the effect, for the researcher, is that derived per capita generation rates will be inaccurate.

The point is that it is important to match the sampling universe to the research question. If you seek to draw conclusions regarding the quantity and composition of waste in an entire wasteshed, then you may sample at the landfill or transfer station. If you want to relate your conclusions to population or commercial activity, then you must have the requisite data on the wasteshed, and trucks and routes. If you seek to draw conclusions regarding the amount and nature of waste generated by households, then you must sample from households. If you also know something about the households, e.g. the number of persons per household, you will be able to draw conclusions about per capita generation.

Along with defining the research question, and the sampling universe, it is important to state clearly of what an individual sample point consists. This may be important in drawing statistical conclusions. A sample point may be a shovelful of refuse, a cubic yard of refuse, the refuse placed at the curb by a household, all of the refuse collected from a neighborhood, and so on. While the merits of each may be argued, let us note for now that in thinking about sampling we should be aware of the unit being drawn as a sample.

3.1.4 Random or Systematic Sampling

It seems obvious that a sample must be "representative" of the population or sampling universe. The notion of representativeness may be regarded, somewhat casually, as indicating that the samples drawn, in aggregate, will be pretty much like the universe. Rigorous mathematical statistics require that samples be random, that is, each "member" of the "population" must, a priori, be as likely to be chosen as any other member of the population.

It is a common practice in many kinds of research to use a systematic sampling scheme as a more convenient substitute for random sampling. A systematic sampling scheme would select every n th member of the population, say every 10 th house, or the first truck to arrive after every 20 th minute, or every 100 th cubic yard of refuse. In practice, systematic sampling is almost certain to be acceptable.

Random or systematic sampling relies on the workings of chance to ensure appropriate representation of all segments of the population. For example if 20% of households in an area are low income, a random sample of sufficient size ought to contain about 20% waste from low income households.

3.1.5 Stratified Sampling

Where it is important to draw conclusions about a subset of the entire population, for example, the difference in composition of waste from low income areas compared to high income areas, it may be desirable to use a stratified sample. In a stratified sampling scheme, samples are deliberately drawn from segments of the population, in sufficient number to make valid conclusions based on the sample from the subset. Stratified sampling may also deliver more precision regarding the entire population with fewer sample points than random sampling.

If low income households were only 3% of all households, say, and 100 households were to be drawn, then you would expect that 3 low income households would be included, though the actual number might be zero or 6. However, it is nearly certain that the amount of data would not justify any conclusions regarding the composition of wastes generated by low income households as distinct from waste generated by any other households. A stratified sampling scheme might deliberately select, say, 50 low income households, and 50 other households. Conclusions about differences between them could be soundly drawn. In order to draw conclusions about the entire population it would be necessary to weight the results from the subsets in proportion to their proportion of the whole.

3.1.6 Avoiding Bias

An estimate of a parameter for a population is said to be "biased" if its "expected value" (average value in a large number of trials) is not equal to the true value of the parameter for the population. Bias would generally mean that a particular estimator is systematically higher or lower than the parameter being estimated. Bias may be introduced into a waste composition study by inappropriate means of selecting or collecting samples.

A clearly expressed concern is that if a sorting crew is permitted to select a sample from a truckload of refuse that they may either select refuse which fits their preconception of what municipal waste should look like, or they may shun waste which is obnoxious for any reason. In either case, the sample would cease to be either random or systematic, and a bias would be introduced. (The person doing the selection must understand the importance of sample selection--the sorting crew must not be allowed to perform the selection unsupervised.)

3.1.7 Sample Size and Statistical Reliability

The matter of statistical reliability should be discussed for two reasons. First, it is proper to indicate statistical reliability in reporting the results of a sample survey of any kind. Second, in designing research, it is necessary to be able determine the size of sample needed to obtain a desired level of precision.

It should be noted that statistical measures of precision discussed here address the matter of the variation due to chance in the sampling process. They do not address matters of bias or validity, i.e. whether the sample mean indeed tends to equal the population mean--or tends to equal something else, and the question of whether you are measuring what you think you are measuring. They also do not address any matters of week to week or season to season variability.

In general, the larger the sample, the more reliable the results of the research. There are two matters to discuss. First is the reporting of results so that the reliability is clearly stated. Second is the determination of the needed size of sample, if it is known how much precision is required.

Reporting the Confidence Level of the Results of Research Involving Sampling

Research involving sampling should report the sample mean, the level of confidence, and a confidence interval (C.I.). A confidence interval states upper and lower limits of a range within which the true value of the parameter for the population should lie.

An example of a confidence interval statement might be that

a particular study that drew random samples from a given waste stream found "8% newsprint, with a 90% confidence interval from 6.9% to 9.1%." This would mean that there is a 90% probability that the actual percentage of newsprint in the waste disposed of during the sample period lies between 6.9% and 9.1%.

Alternatively a confidence interval may be expressed as a percentage of the sample mean, for example as "plus or minus 10%." This way of expressing the confidence interval is often used in waste composition studies. It should be noted that if a confidence interval is expressed as plus or minus some percentage, the associated level of confidence will differ from parameter to parameter; for example, if the sample mean for one parameter is 30%, there would be a higher degree of confidence in the +-10% confidence interval than for another parameter with a sample mean of 5%.

Confidence intervals are most often reported so that they are symmetrical about the sample mean, but they do not have to be. It is possible, and sometimes appropriate, to report a one sided confidence interval, for example, to report that there is a 95% confidence level that a parameter does not exceed a particular value.

In order to determine a confidence interval, it is necessary to know the number of sample points in the sample, the sample standard deviation , the form of the sampling distribution, and--if the population is "small"--the number of points in the population.

It is common practice to use the normal distribution for confidence interval determination. Under certain circumstances it is permissible to use the normal distribution even though it is known that data is not actually distributed normally. It may be possible to transform data which is not normally distributed so that it becomes normally distributed. It may also be possible to use samples that are large enough that the "Law of Large Numbers" justifies the use of the normal distribution. The "Law of Large Numbers" asserts that, as sample size is increased, the distribution of a sample mean will tend to approach a normal distribution regardless of the distribution of the parameter in the population. This matter is discussed further in the discussion of sample size for composition estimates, below.

Designing Research: Required Sample Size as a Function of Desired Precision

The discussion above centered on the reporting of the results of sampling. The other side of the statistical reliability coin is the question of how large a sample is needed in order to obtain a given level of precision. The degree of precision needed depends on the purpose of the study and often on the monetary value of a correct decision versus an incorrect one. Since precision is obtained primarily through larger samples, the

desire for great precision is balanced against the research budget.

Since confidence intervals may be calculated only when the distribution and standard deviation of the population data are known, it may be necessary to perform a small scale study in advance of the main study, in order to obtain this information and determine sample sizes.

Research on appropriate sample sizes was reported in a study by SCS Engineers for EPA.[1] The study addressed the required sample sizes for precision in solid waste composition studies. The purpose of the SCS report was to provide a protocol for studying waste streams for the purpose of Waste to Energy Incinerator design. A study protocol was needed that would provide adequate estimates of both quantity and composition.

SCS noted that precision requirements vary widely. For Resource Recovery plant design, quantity estimates within +-10% at a 90% confidence level are probably sufficiently precise. Composition estimates are also important, because the results may bear on the thermal characteristics of the waste. For composition estimates, +-10 to 20% at a 90% percent confidence level appears to be reasonable.

Sample sizes needed for quantity and composition, according to SCS pilot studies, are reported are reported below in the sections on quantity survey protocols, and composition protocols.

3.1.8 The Importance of Careful Planning, Preliminary Research and Competent Management

Actual data collection will be expensive and difficult. The importance of thorough and careful preparation prior to the conduct of a survey cannot be overemphasized.

Preliminary planning should include wasteshed mapping, collection of demographic information on the wasteshed, contact with operators of landfill and transfer station facilities, and contact with haulers. At least one study noted that haulers would not cooperate in sharing information on collection routes, and that as a result, it was impossible to accurately assess waste generation by sources. [2] In another instance, a landfill operator persisted in denying access to the privately operated landfill, until the principals in the study visited her with a gift of roses. [3]

An understanding of the importance of the study may be communicated to facility operators and haulers through prior contact, and due consideration may be given to adapting the study in order to cause minimal disruption to day to day logistics.

The location of the survey should be visited and specific locations identified for the operations to be carried out should be arranged. All necessary equipment should be obtained in advance and the operational condition of the equipment should be verified. Equipment breakdowns have been cited as a problem causing loss of productive survey time. [4]

Data recording forms should be available in advance, and data reduction and analysis should be planned ahead and tested. If a computer is to be used, software should be pretested. At least two studies cited various data recording failures as the cause of having to discard some data, or to undertake time consuming follow up work to obtain information on trucks (information that should have been recorded at the landfill), in order to make certain data useful.

Finally, with all of the preparations done carefully, it is necessary to attend to the performance of the sorting crew. It must be recognized that sorting garbage could be regarded, on the surface, as an undesirable activity, and laborers who are not well motivated may perform poorly in either speed of sorting or in care given to accurate work. The quality of the result is completely dependent on the performance of the sorting crew.

SCS Engineers suggest that paid laborers are more productive than unpaid volunteers. [5] A daily quota is a common feature for sorting crews, with the crew permitted to leave for the day when the specified number of samples have been sorted.

In the case of a study in Atlantic County, New Jersey, it is believed that high crew morale was maintained, in part, through a combination of taking the crew off-site at lunch time and buying them lunch, and by ensuring that everyone involved in the study took a turn at sorting--supervisors and project directors included.

It is, of course, important that each crew member be properly equipped and clothed. Heavy boots, coveralls (nylon or rubberized rather than cotton), and heavy rubberized gloves should be standard. If conditions are dry and dusty, dust masks should be provided. Suitable shovels, rakes, tongs, and so on should be provided. The importance of careful work should be communicated to the crew, and sufficient training in recognizing relevant material categories should be provided.

3.2 Waste Quantity Survey Protocols

Data on the total quantity of waste entering a solid waste facility will probably be desired. This is certainly the case if the purpose of the study is design of resource recovery or solid waste disposal facilities. It may also be desired for recycling studies, particularly where it is desired to convert composition analysis to per capita generation rates of various materials.

There are two means of obtaining reliable quantity information. The first choice would be complete scale records, where every truck is weighed both entering and leaving the landfill or transfer station. Second, where scales are not available, a sample of trucks may be weighed, and density factors (pound per cubic yard) derived, in order to estimate waste quantity from a count of trucks entering the facility.

3.2.1 Weight Determined by Complete Scale Records

Complete weight records are very much the preferred means of waste quantity determination. The most desirable situation is one in which platform scales are part of the disposal facility operation, and every truck is weighed when entering and again when leaving, on a year round basis. This becomes, in effect, a complete census of waste quantity, and allows accurate assessment of seasonal variations in quantity, trends with time, and so on.

Not quite as good, is complete weighing of trucks during a waste quantity survey period such as one or two weeks. Such a method provides accurate data for the survey period, but the survey period must be carefully chosen in order to avoid certain biasing factors. For instance, holidays are known to affect waste generation; both holiday periods and the periods immediately after holidays should be avoided. It is important to continue quantity surveys for at least a full week. It has been observed that waste quantities tend to be at a maximum on Mondays, with a tendency to decline during the week, and with Saturdays being lower than weekdays. A survey conducted on a single day and generalized to a full week would probably be very inaccurate. [6]

Finally, if complete records are not available, quantity surveys must be repeated at different seasons of the year. Even where there is no significant seasonal population, waste quantities and composition vary with the season. It has been noted that yard waste is at a maximum in the fall.

3.2.2 Weigh Sample of Trucks to Establish Density Factors, Apply to Truck Count by Size.

If scales are not available to weigh each truck, a sample of trucks may be weighed in order to establish "pseudo-densities" that may be applied to truck counts. The idea of a pseudo-density is that the weight of the payload is divided by the nominal volume of the truck, as if the truck were full, regardless of the actual fullness of the truck. This eliminates any need to estimate partial loads, and relies instead on a statistical inference.

It is important to weigh a sufficient sample of trucks to obtain the desired degree of precision. The number will vary depending on the number of trucks entering the landfill, the variability of the particular data, and the precision desired.

The number of truck weights needed will probably be in the range of 20 to 125. It is extremely important that random or systematic sampling be done throughout the day. Truncation of sampling before the end of the day will tend to sample only full trucks, failing to obtain weight samples from partial loads, which are much more likely to enter the landfill later in the day. [7]

Based on field work done during research on waste characterization protocols, SCS Engineers found that the following sample sizes would be required for load density estimation. The landfill used for field work was used by 6 major truck classes, with possible variations in density between classes of truck. It was found that using stratified sampling allowed the use of slightly smaller sample sizes. [8]

Table 13: Sample Sizes Required for Load Density Estimation at 90% Confidence Level and Stated Precision According to SCS Field Survey

Trucks Entering Landfill/wk	+-10%		+-5%	
	Stratified	Random	Stratified	Random
<75	19	23	43	48
76-100	21	25	52	57
101-150	23	27	63	70
151-300	25	30	79	91
301-500	26	31	89	103
501-1000	26	32	97	115
>1000	28	34	104	124

3.3 Waste Composition Survey Protocols

3.3.1 Random 200-300 Pound Sample of Entire Waste Stream and Hand Sort

The most common method of waste composition analysis has been some variation on the selection of random 200 to 300 pound samples from the entire municipal waste stream, with materials hand sorted. This appears to have almost become a standard method of waste flow characterization for the purpose of resource recovery plant design. If careful work is done to document the waste shed, the demographics of the waste shed, and collection routes, useful results for planning recycling systems may be drawn from these studies.

Sampling

The sampling universe in this protocol is the entire municipal solid waste stream, as delivered to the disposal facility. Samples are drawn by selecting trucks from which a grab sample is drawn. Trucks may be selected at random, or

systematically from all of the trucks entering the facility. A typical truck selection scheme would involve a random starting time, followed by the selection of the first truck to arrive after every 20th minute.

A refinement to this process was suggested by the statistical consultant to an Ann Arbor Michigan study, who pointed out that it would be preferable to select the truck that is found to be carrying every n th cubic yard of waste. [9] In this way, the systematic sampling simulates random sampling in which every cubic yard of waste is, a priori, equally likely to be selected, as opposed to every truck being equally likely to be selected. By keeping a running tally of the cumulative cubic yardage of all trucks entering the landfill, and selecting the truck carrying, say every 100th cubic yard (150th, 250th, 350th, and so on), more large trucks will be chosen, which is appropriate. This is a preferable procedure from a statistical point of view. However, it may be less convenient to work with in the field, since closely timed arrival of trucks may make the required amount of sample extraction impossible within the time available. In that case, the selection based on arrival time would probably yield virtually identical results. The use of the every n th cubic yard method should be used for truck selection if it is found to be convenient. It could be abandoned with little or no harm if it is found to be impractical or inconvenient.

An alternative to random selection of trucks as they enter the landfill is the preselection of trucks, either by means of a random number table, or through a stratified sampling scheme that selects trucks to represent various socioeconomic neighborhood, and an appropriate mix of residential and commercial trucks. SCS notes that pre-selection of trucks is likely to cause the study to be more expensive, due to the loss of sorting time while waiting for selected trucks to arrive. The 1978 variable costs of stratified sample sorting was $16.61 per sample, versus $10.61 per sample for the random or systematic selection method. [10] The potential advantage of stratified sampling is greater precision for a given amount of sampling.

Field Procedure

Once a truckload for sampling has been selected, the driver is directed to dump the load in a predetermined location. It has been noted that it is desirable to use a concrete pad as the dumping location, if possible, in order to avoid the mixing of dirt with the refuse.

A "grab sample" of 200 to 300 pounds is then selected from the dumped truckload of refuse. There are two important issues involved in obtaining the sample; one is the choice of the location from which the sample is extracted, and the other is the mechanical method of obtaining the sample.

The choice of location of the sample is done via some random

or systematic means, in order to preclude bias introduced if the sorting crew were to perform the selection. It is generally asserted that a sorting crew will choose either waste which meets their preconception of what municipal is supposed to look like, or alternatively, that they will avoid waste which is messy or unpleasant. To avoid these problems, the starting point for sample extraction is done either by means of a randomly chosen quadrant (N,E,S,W) or by placing a rope grid over the pile, and selecting an intersection of ropes via random numbers.

With a starting point selected, a sample must be extracted. The method used has varied, from study to study, on the equipment available. When heavy equipment is available, most often a front end loader, it is generally asserted that it is desirable to extract a sample in one motion, with no disturbing or mixing of the material in the load. An Ann Arbor study made use of a specially modified scoop on a front end loader, to minimize the extent to which large objects, once in the scoop, did not fall out. [11] Where heavy equipment has not been available, the crew, by raking and shoveling, have accumulated the required sample size a little at a time. It would appear that hand labor could be inferior to mechanical extraction, if the accumulation of small amounts of waste permitted crew selection of the waste to be included, or if some mechanical bias against large or small objects were introduced.

In some instances a bulldozer has been used to knock the edge off of the pile, so that either a mechanical scoop, or crew members armed with rakes and shovels, would have ready access to the interior of the dumped load.

A sample, once extracted, is placed on a plastic tarp, and hand sorting begun. As many containers as needed, at least one for each category of material, surround the sample. When all of the pickable, classifiable items have been placed in containers, the remaining fine material is screened and weighed.

The weighing process has been somewhat variable, among the studies reviewed. The SCS protocol recommends, and their pilot studies utilized, weighing after each sample. This provides the opportunity to base measures of statistical variability on many sample points, that is, the sample standard deviation is based on the variation among 200-300 pound samples. In other studies, material has been accumulated throughout the day, with the only weight reported being the amount and percentage of each material accumulated from the entire day's sorting of 2,000 to 4,000 pounds. The later method reduces the amount of labor involved in weighing and recording after each sort, and allows for greater precision in the overall weighing, since small errors on each sample have no chance to accumulate. The use of only the accumulated weights may sacrifice some opportunity to calculate statistical confidence intervals, and may blur distinctions between waste sources, if different sources are mixed in the sorting bins prior to weighing.

Optimum Weight of Samples for Sorting

The SCS study addressed the optimum size of samples, the appropriateness of using the normal distribution for statistical precision calculations, and the number of samples needed to obtain acceptable precision.

SCS concluded that 200 to 300 pound samples were optimum. While transformation may result in more normally distributed data, SCS concluded that prior studies indicate that is usually acceptable to use the normal distribution; while some precision in the calculation of the confidence interval may sacrificed, the results will be close and the added ease of calculation is considerable. With respect to the number of samples needed, this section concludes with representative tables based on SCS field work.

In other other research examined by SCS, Carruth and Klee reported that percent composition data became more normally distributed after being transformed by Yi=2*arcsin(sqr(Xi)), where Yi is the transformed value and Xi is the percent composition by weight. (Note: sqr is the square root function, i.e. take the square root of Xi) In their study, no precision was gained when samples increased beyond 90.8 kg or about 200 lb. [12]

Another researcher, Britton, simulated samples, and concluded that the normalizing transformation was not usually needed, particularly if the sample was closer to 300 pounds than 200 pounds. [13]

Based on the cited research, SCS concluded that the use of samples of at least 200 to 300 pounds should be sufficient to justify the use of the assumption of normality, and further, that the use of larger samples would be more costly and would not result in appreciably more accuracy. [14]

The Number of 200 to 300 Pound Samples Needed

If all percentages are normally distributed, and estimates of mean and standard deviation are available, then (some contend) the number of samples required for precision $|x-d|$, at 1-a degree of confidence, is given by:

$$n=(((Za/2)*s)/|x-d|)**2$$

where Za/2 is the standard normal deviate for a 1-a degree of confidence.

SCS test sampling found different degrees of composition variability at different sites, with resulting differences in the required number of samples needed to obtain a given degree of precision. The following table summarizes the best and worst case

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sampling number requirements for 90% C.I.

Table 14: Number of Samples Required for Solid Waste Composition Estimates: [15]

Best Case, Residential Waste Only, (90% Confidence level)

	Sample Mean	Sample Standard Deviation	+- percent precision 5	10	20	30
Ferrous	.050	.021	194	50	14	8
Aluminum	.012	.006	275	70	19	10
Glass	.066	.024	146	39	11	6
Corrugated	.052	.047	899	225	58	27
Newsprint	.082	.037	224	58	16	9

Worst Case, Residential Waste Only, (90% Confidence level)

	Sample Mean	Sample Standard Deviation	+- percent precision 5	10	20	30
Ferrous	.031	.022	554	139	37	18
Aluminum	.007	.008	1437	360	92	42
Glass	.056	.042	619	155	41	19
Corrugated	.054	.072	1955	489	123	56
Newsprint	.084	.124	2397	600	150	68

Note: This would mean, for example, that in order to be 90% confident that you had estimated the true percentage of aluminum in the waste stream within plus or minus 10% of its true percentage, in the worst case, you would have to take at least 360 samples of 200-300 pounds.

3.3.2 Random Sample of Entire Waste Stream, Cone and Quarter and Mechanical Sort

Several studies have used much larger samples, drawn by means of coning and quartering, followed by mechanical sorting. These studies have invariably been for resource recovery incinerator design, or update studies. A prime example is a series of studies done for the Delaware Solid Waste Authority (DSWA). [16],[17] DSWA operates a complex resource recovery plant that mechanically sorts waste to recover material and resource derived fuel.

In the coning and quartering technique, trucks have been selected for sampling, and it has simply been asserted that the routes served by the trucks are representative of the entire

service area. The entire truck load, or in some instances, several truckloads, are mixed and pushed into a cone shaped pile by a bulldozer. In a modified quartering technique, the center of the pile was then pushed out for collection by bulldozer.

The extracted sample, weighing some 2.5 to 3.5 tons was then taken to a Bureau of Mines pilot plant for mechanical sorting. The mechanical sorting involved shredding, air classification, magnetic separation, and water. No hand labor was involved.

DSWA claims that this method has produced estimates of waste composition and fuel characteristics which have been borne out by experience in their solid waste facility. However, the information is not useful for recycling, since the categories resulting from the mechanical sort do not identify recoverable materials. For example, only "paper" and "glass" appear as categories, with no identification of "newspaper", or "clear glass","green glass", "non-beverage glass", and so on.

3.3.3 Hand Sort of Entire Truckload

Another approach to obtaining composition data for resource recovery plant planning was described by Hollander. [18] The approach described was the sorting of five entire truckloads of refuse.

Hollander asserts that the coning and quartering of refuse is inappropriate, since refuse is "heterogeneous, coarse and fine, dense, compressible, loose or bagged, will not flow or mix, and will segregate." The efficacy of selecting small 200 to 300 pound samples is also questioned by Hollander.

The truckloads sorted ranged in size from 5,200 to 22,900 pounds, and a total of 65,800 pounds of refuse were sorted. The approach avoids the issues of the appropriate size of a grab sample, and the issue of sample extraction from the truckload. These advantages are balanced by the extreme reliance placed on the representativeness of the particular truckloads chosen for sorting.

The trucks were chosen by the Central Wayne County Solid Waste Authority superintendent, who, it is asserted, is "fully conversant with the residential areas served by the collection trucks.." Unfortunately, no demographic information is presented on either the entire service area, or the routes served by the trucks whose loads were sorted, so it is quite impossible to verify that the selection of trucks was indeed representative of the service area.

It would appear that the extreme reliance on a limited number of rather arbitrarily chosen trucks is a weakness in this method. The prodigious amount of sorting required would probably be better utilized to sort more smaller samples, which because of a random or systematic sampling scheme, would have some

statistical guarantee of being representative of the service area.

The approach of sorting an entire truckload may have merit, if the route chosen is one for which relatively complete demographic data is available. For example, a census Block Group or Enumeration District, which is generally intended to contain around 800 persons, would make up a truckload of refuse, and complete census data could be related to that truckload of refuse. In the absence of a demographic link, it would appear that the entire truckload approach makes poor use of a great deal of sorting labor.

3.3.4 Curbside Pickup at Sample Households

Two of the studies reviewed collected samples at curbside from sample households. One of these was USEPA's study of Somerville and Marblehead Massachusetts, and the other was a study of Milwaukee Wisconsin.

In the study of Somerville and Marblehead Massachusetts[19], trash and source separated materials were collected at curbside from 3 to 20 housing units, until a 250 to 300 pound sample had been accumulated for sorting. The neighborhoods were chosen to be representative of the communities.

When both refuse and source separated material had been sorted and weighed, the component percentages in each category were applied to municipal records of total refuse disposed of and total source separated material recycled, in order to calculate the recovery rate for each material.

The merit of the approach is that the final result provides very pertinent information for recyclers in its comparative analysis of the relative success of recycling efforts in two communities, and in the relative success at diversion of different materials in each program. The potential weakness is mixing of sample data with administrative records to draw out the apparent recovery rates. The report is strong in terms of presenting demographic and settlement pattern data on each town.

In the Milwaukee Garbage Project [20], the researchers collected samples from households, one at time, and conducted their sorting and analysis on a household by household basis, without accumulating or mixing the samples. A "garbage pickup" was the unit of analysis, where a pickup was the material placed at the curb by one household. Given that pickups were made on a once weekly basis, the pickup represented one week's waste generation for one household.

Demographic information was collected on the census tract in which the households were located, but no information was collected on the individual households. Even with tract data

available, only households with separately identifiable garbage set out were eligible for collection. This eliminated from consideration households living in apartment buildings. The tract level census data included the apartment dwellers, however. The looseness of the application of demographic data precluded the possibility of deriving per capita generation rates, and made the income levels of the various sampling areas somewhat uncertain.

The level of analysis of the household refuse in the Milwaukee project was much more detailed than any other study reviewed. Some 153 categories were used for detailed sorting! This reflects the interests and academic orientation of the authors who are PhD anthropologists, with a considerable interest in relating waste composition to culture and consumption patterns.

3.3.5 Voluntary Delivery by Sample Households

A 1974 study of Nottingham, New Hampshire [21], utilized voluntary delivery of household refuse and separated recyclables to a small scale recycling facility. Nottingham was a small rural town with a year round population of about 1,200. Many if not most of the residents delivered their own waste to the dump, though some residents were served by commercial service. The setting dictated the slightly unusual sampling method.

Of 450 houses in the study area, 150 households were selected for an attitude survey, and from those, 62 households agreed to participate in a weighing study. For a period of approximately one month (8/3/74 to 9/11/74), participating households were asked to deliver both their separated recyclables and their rubbish to the town's recycling center. When they delivered the materials, they were asked how many days accumulation was included. The number of persons in each household was elicited, and weights delivered related to a record of number of people.

The study found an average total waste generation of about 2.1 lb/cap/day of which a little over half was separated recyclables. The authors note that small town generation rates may be lower than large town rates, and that they collected only residential waste, with no commercial or industrial waste included. They further note that seasonal variation is probable, but that they conducted a study for only one month. (The larger purpose of the study was an economic analysis of a small recycling plant).

In addition to the limitations noted by the authors, it should be recognized that the fact that households participated only if they agreed to participate could be a biasing factor. A second factor, is the fact that any form of special attention tends to alter people's behavior. The seemingly high rate of recycling relative to the total waste stream could be due at

least in part to a feeling of continued scrutiny of the households' recycling performance during the study. There is no way of knowing what effect these factors may have had on the study. Working in a situation that did not lend itself to the usual sampling schemes, the authors devised a way to adapt to the surroundings and perform a study in spite of limitations.

3.3.6 Product-Materials Flow Analysis

An altogether contrary notion to the sample and sort schemes that solid waste field studies utilize is to model the waste stream in an "input-output" or mass balance computation. The central idea is that if product composition is known, and product sales are known, and if the average life of the product is known, then it is theoretically possible to calculate the amount of various material that must be discarded.

The method is discussed by Fred L. Smith, for USEPA. Smith asserts that sampling results are specific to the time and place of the sample, and thus cannot be easily extrapolated. However, the results of his calculation were adjusted to selected waste sampling data. In addition, Smith notes a number of practical difficulties; in particular, he notes that very extensive data must be available.

This is the method used in the preparation of the United States Environmental Protection Agency's Fourth Report to Congress: Resource Recovery and Waste Reduction. The limitations of the method for local data are noted.

> "The material flows approach utilizes detailed U.S. government and industry trade association statistics on material consumption and product shipments to household and commercial sectors in deriving solid waste generation estimates. While this approach yields reasonably accurate estimates for most of the manufactured goods components of the waste stream, the food and yard waste estimates can be considered only rough approximations. In addition, the estimates presented are indicative only of U.S. nationwide totals or averages. Since there is considerable regional variation in waste generation, collection, and recycling rates, these nationwide figures should not be used for local planning purposes." [22]

Other researchers make use of the materials flow approach as an adjunct to other methods, or as a way to estimate part of the waste stream. Tichenor compared the results of sampling to sales data from local supermarkets, with respect to beverage containers. Rouleau (Vermont) used beverage sales data, coupled with container mix data to compute the number of pounds per capita per year of various beverage containers. Powell (Atlantic County N.J.) collected circulation data for all of the newspapers published in a county, and weighed a week's accumulation of each paper in order to estimate the total amount of newspaper that

might potentially be recycled. [23]

Product-materials flow analysis cannot be recommended as an alternative to sampling for either waste composition or waste quantity studies. However, it may be useful for sensitivity analysis to test the effect of a changing packaging mix on waste composition, and on recycling and resource recovery economics.

3.3.7 Dealing With Private Vehicles

At least two studies had to deal with situations where a significant quantity of waste was delivered by private vehicles such as autos and pickup trucks, rather than large volume compactor trucks.

In a study for Sullivan County, NH, and Windsor and Windham Counties, VT, the objective was the determination of the quantity of solid waste disposed at a rural landfill. A 30 cubic yard compactor was used to collect waste delivered in cars and pickup trucks. The compactor was weighed at the end of the day. [24]

A study of the Berkely California landfill was primarily concerned with the willingness of landfill patrons to use proposed recycling facilities. Interviews were conducted at the landfill face, and the total amount of waste and the composition of the waste was visually estimated by the interviewer. [25]

A sensible approach to fairly representing waste delivered by autos and pickup trucks in a rigorous composition study would be the use a compactor truck or roll off to accumulate the small loads, and then sample from the accumulated load as if it were one of the vehilcles entering the facility. The remarks above regarding the desirability of sampling every n th cubic yard of waste would apply.

3.3.8 Recommendations

Solid waste characterization will no doubt continue to make use of a variety of methods, reflecting varying objectives, varying budgets, and the peculiarities of different situations. Product/material flow analysis will continue to be appropriate for a nationwide overview, and for sensitivity analysis. However, recyclers and other solid waste managers will have a need to study local conditions via field studies.

Two approaches to solid waste field studies appear to warrant favored consideration for recycling planning. They are:

1) Sampling at the disposal facility and hand sorting, and;

2) Sampling at the point of generation, which for residential waste means the neighborhood.

Sampling at the Disposal Facility

Sampling at the disposal facility is appropriate when the highest priority is accorded to a characterization of an entire waste stream. This will be the case when overall planning for waste management is the goal.

The particulars of sampling and sorting at the point of disposal have been described, and an adequate literature exists to provide details of the method. Planning for resource recovery plants will involve waste generation and composition studies. Recyclers should have input in the planning stages of the study, because minor alterations or additions to the protocol will make the results much more useful for recycling planning. In order to make such a study useful for recycling planning, these conditions should be included in the study design:

1. The classification scheme should consist of categories that are meaningful for recyclable material collection and marketing. This will mean that some additional detail will be required, and it could mean that classification by product as well as material will be appropriate. It may also mean that in the conduct of the study some materials will be subjected to a secondary sort, if the material in question must be marketed according to a large number of grades.

2. Adequate documentation of waste sources should be provided. This includes both geographic sources, and appropriate distinctions between residential, commercial, industrial, and institutional sources of waste.

3. The population of the wasteshed should be reported, along with base line demographic information, income levels, and type of housing. All of this should be available from census data and/or a State Data Center. General land use information should be reported and the nature of the area a described in terms of intensity of development, size of place, and so on.

4. With the above conditions satisfied, it should be readily possible to report per capita generation rates for various materials on a daily or annual basis. Rates expressed on a daily basis should be reported on the basis of seven days per week, not per collection day, and the seven day per week basis should be clearly stated in the documentation.

Sampling Within Neighborhoods

Sampling at the point of generation is appropriate when it is desired to know the amount of recyclable material that can be collected by a recycling program, and the amount of solid waste that would not be landfilled or incinerated as a result. Conclusions regarding existing or proposed recycling programs

have often, of necessity, combined and manipulated information from a variety of sources. Where extreme inventiveness has been required, the validity of some of the results may be questionable.

Valid conclusions regarding recycling program effectiveness could be drawn from a rigorous study of residential waste generation and recycling program effectiveness could be conducted by sampling within a neighborhood.

The unit of analysis would be a census tract or census block group. Census data would serve as demographic and housing data for the sampling universe. The households in the neighborhood would not know that the study was being done, so they would not alter their behavior as a result. In parallel with the way that opinion poll samples are drawn, a collection of block groups or tracts could be chosen to represent a demographic cross section of the entire waste shed or metropolitan area.

Collection routes for both waste and recyclables could be modified so that the all of the material left at curbside within the study area is collected in a single vehicle. No waste from outside of the study area would be collected in the same load. The total amount of waste and recyclables from each block group or tract would be determined by scale weights.

Composition analysis would be drawn from hand sorting of samples. Because the number of trucks involved would be small, several 200 to 300 pound samples would be drawn from each collection vehicle. It is possible that the entire contents of the vehicle would be sorted, depending on the particulars of the study.

This approach would offer several advantages over the "catch as catch can" means that have often been used to evaluate recycling programs.

1. The demographics of the study area would be known. There is a caveat that rapidly changing areas may no longer be well described by census data that is over 5 years old. Never the less, census data is generally the most reliable demographic base data that is available. Per capita generation rates and other demographically based conclusions should be reasonably reliable.

2. Real, rather than speculative, rates of recyclable separation and collection may be established.

3. The effectiveness of differing programs may be evaluated. For example, the change in material collection following a publicity and education campaign may be well documented at the neighborhood level.

CHAPTER 4 HOW TO OBTAIN AND USE DEMOGRAPHIC DATA

Demographic data may be useful in several ways. First and most obvious is that per capita generation rates, or recovery rates, may be applied to population counts. This provides a means of doing preliminary planning for material recovery, energy recovery, and waste disposal.

Second, it has been noted that participation in source separation may vary greatly between different areas. In the Somerville/Marblehead study, the major differences in the success of the programs appeared to be related, not only to differences in the operation of the programs, but also to differences in demographics, housing stock, and urbanization patterns of the towns. Marblehead, where the participation rate was much higher, featured higher income, higher education, lower density per square mile, a much higher percentage of single family homes, and a much higher percentage of homeownership. [1]

Third, there are indications that consumption patterns, and therefore waste production, vary with demographics. In particular, it appears that higher income is related to greater generation of newspaper and yard waste. Conversely, lower income appears to be related to greater generation of packaging waste. [2] Both age and income appear to affect beverage consumption. Lower income households appear to consume relatively more beer and soda. Teenagers consume the greatest amounts of soft drinks. [3]

None of this is intended to suggest that simple reliable means exist to predict the amount or composition of waste that will be produced from a given area, nor does it imply that the success of a recycling program would be determined purely by demographic factors. However, given the importance of demographic factors, it is clearly advisable to have appropriate data at hand when planning either a waste composition study or a collection or disposal system.

4.1 Use and Availability of Data

Demographic and related data should be used in both survey planning and survey reporting. At the very least, if waste stream sampling is utilized, consistent reportage of demographics of the wasteshed will eventually permit useful comparisons to be made between various areas of the state. If relatively small geographic areas are used to represent a larger area, then it becomes vitally important that either 1) the demographics of the sample area match the demographics of the larger area, or 2) if several sample areas are used, the demographics be known so that appropriate weighting may be applied to produce a composite result that accurately represents the larger area.

4.2 Recommended Data Items and Sources

The following data is recommended for both survey planning and waste management planning:

- Census data
  - Population
  - Households
  - Housing units
    - 1 or 2 units at address
    - 3 or 4 units at address
    - 5 or more units at address
    - owner/renter occupied
  - Income
- Economic Data
  - Census of Retail Trade
  - Employment by SIC code
- Other Data
  - Area
  - Settlement pattern

4.2.1 Census Data

The most useful source of census data is a pair of Census Bureau computer tapes: Summary Tape File 1 (STF-1), and Summary Tape File 3 (STF-3). While much of the same data is reported in Census Bureau printed reports, the computer tapes offer two important advantages. First, the data is available for all levels of geography, beginning with the state, and progressing downward for counties, municipalities, tracts, Census Designated Places (which split tracts in some instances), and Block Groups or Enumeration Districts. Some STF-1 data is available at the block level, where a block is an area bounded by streets. Second, because the data exists in machine readable format, the opportunity exist for further manipulation of the data without tedious and error prone hand entry of data.

Selected census data is also available on microcomputer diskettes, both from the Census Bureau and from private data firms. The Bureau's diskette data packaging has, so far, been oriented toward relatively large geographic areas; for example, one of the available products is the City and County Data Book. Private firms appear to offer finer geographic detail. Private data products are primarily aimed at market researchers, and typically include proprietary indices of market potential for various classes of retail sales. Both private firms and some University computer centers may be able to prepare custom datasets on diskettes.

The following census data is available on Summary Tape File 3 and appears to be useful for waste survey and recycling program planning. Much more data is also available on STF-3. In the list below, the STF-3 table number is identified in parentheses.

Table 15: Census Data of Potential Use in Recycling Program Planning Available on STF-3

FIPS codes identifying state, SMSA, county, MCD, place, tract

Persons (Table 1)

Persons by race (Table 12)
- White
- Black
- Other (derive by grouping or subtraction)

Persons of Spanish origin by race (Table 14)
- White
- Black
- Other (derive by grouping or subtraction)

Persons by Spanish origin and race (derive this table)
- White not of Spanish origin
- Black not of Spanish origin
- Spanish origin
- Other not of Spanish origin

Persons by age (Table 15) (derive categories by grouping)
- Under 5
- 5-9
- 10-19
- 20-34
- 35-44
- 45-64
- 65 and over

Persons by urban/rural (Table 4) (I don't know if this is useful)
- Inside urbanized areas
- Other urban
- Rural

Comment: Inside urbanized areas, and other urban, may roughly correspond to "large" and "small" places as discussed in various solid waste planning documents.

Persons by farm/non-farm (Table 7) (Again, is it useful?)
- Rural farm
- Rural non-farm

Persons in households (Table 18)

Households (Table 10)

Persons per household (derive)

Table 15: Census Data of Potential Use in Recycling Program Planning Available on STF-3 (cont.)

Persons 25 years and over by years of school completed (Table 48)
- Elementary (0-8)
- High School
  - 1 to 3
  - 4
- College
  - 1 to 3
  - 4 or more

Median years of school completed by persons 25 and over (derive)

Household income in 1979 (Table 68)
(combine ranges as desired..one possible array follows)
- Less than $7,500
- $7,500 to $9,999
- $10,000 to $14,999
- $15,000 to $19,999
- $20,000 to $29,999
- $30,000 to $49,999
- $50,000 or more

Median household income in 1979 (Table 69)
Comment: probably the best single measure of income level of an area.

Housing Units Total including vacant, seasonal, and migratory (Table 6)

Year Round Housing Units by Occupancy Status (Table 11)
- Total
- Occupied
- Vacant

Vacant Housing by Vacancy Status (Table 96)
- For sale
- For rent
- Held for occasional use
- Other

Occupied Housing Units by Tenure (Table 97)
- Total
- Renter occupied

Housing units (derive this table from above tables)
- Total
- Seasonal and migratory plus year round held for occasional use
- Year Round except held for occasional use
  - Occupied
    - Owner occupied
    - Renter occupied
  - Vacant

Table 15: Census Data of Potential Use in Recycling Program Planning Available on STF-3 (cont.)

Housing units by Units at Address (Table 102)
- Total occupied
  - 1, detached
  - 1, attached
  - 2
  - 3 and 4
  - 5 or more
  - Mobile home or trailer, etc.
- Renter Occupied
  - (repeat units in structure)
- Comment: This enables the identification of rental apartments as a housing type.

Year Round Housing units by stories in structure (Table 105) (This may not be useful)
- 1 to 3
- 4 to 6
- 7 to 12
- 13 or more

Persons in Occupied Housing Units by Units in Structure by Tenure (Table 104)
- Total
  - 1, detached
  - 1, attached
  - 2
  - 3 and 4
  - 5 or more
  - Mobile home or trailer, etc.
- Renter Occupied
  - (repeat units in structure)
- Comment: This enables counting the population in rental apartments, among other things. The number of persons in owner occupied housing units may be derived by subtracting renter occupied from total.

4.2.2 Economic Data

The primary value of economic data would be the identification of areas with significant amounts of commercial activity, which are an important source of waste generation that is more or less independent of population and households.

The census of retail trade reports on the number and type of establishments, and the number of employees and amount of sales. The fineness of the geographic resolution is limited however, with most data presented at the county level, or for "Major Retail Concentrations" (MRC's), which are roughly equivalent to a major regional shopping mall.

Employment by SIC code should be available from Massachusetts State Government. It will indicate, at the county level, the

number of employees in a very detailed breakdown of type of enterprise. At the municipal level, detailed SIC breakdowns are often suppressed in order to preserve confidentiality, but broad SIC groups will be reported. Total employment by municipality should be available. Field work or interviews may enable reasonably accurate estimates of employment by SIC code at the municipal level.

Smith indicated the possibility of applying generation rates to employment by SIC code to model waste generation by composition. [4] While his suggestion may have been overly optimistic, employment by SIC should be useful to indicate, at the municipal level, where there are significant commercial concentrations. It is entirely possible that future waste generation and composition studies will verify that at least per employee generation rates may be used for retail SIC codes.

4.2.3 Other Data

The area in square miles of each municipality should be coupled with population to obtain a density of population per square mile. In addition, a qualitative description of the nature of the area should be obtained from county or regional planners. This is because it has been noted that there may be important differences in waste generation, disposal, and collection, and likewise differences in source separation participation, among areas, and those differences often have some correlation to density and settlement pattern. The conclusions drawn from this information will likewise be qualitative, but in the long run may be very instructive and useful in program planning.

4.3 Data for Survey Planning

4.3.1 Data for Waste-shed, and Major Subareas

If it is desired to draw samples from the waste stream, i.e. at the transfer station or landfill, an adequate characterization of the waste shed should be required. This would require, first, that the waste shed be identified by careful interviewing of haulers to determine the areas covered by collection routes. In most cases, waste sheds will consist largely of collections of complete municipalities. Census data for entire municipalities may be safely accumulated into a total for the entire area. In some instances, it will be found that only a portion of the waste from a particular municipality may enter the sampled facility. In that instance, it must be decided on a case by case basis how to estimate the population served and its demographic characteristics. If collection routes can be accurately drawn, it is possible that census tract data can be used to account for portions of municipalities. Otherwise an experienced practitioner will have to prepare reasonable estimates based on available data, aerial photos, and any other available information.

4.3.2 Data at Enumeration District (E.D.) or Block Group (B.G.) Level For Neighborhood Samples

An alternative to sampling from the waste stream is to sample from neighborhoods or individual households. When this is done, the neighborhood or household itself is a sample point taken from a sampling universe that consists of the entire region. This form of sampling would be particularly appropriate for studies of residential waste generation, and studies of participation in source separation and resulting material recovery.

While a single Enumeration District or Block Group might in theory represent a cross section of the society, the degree of racial and economic segregation that most areas exhibit make it much more likely that a collection of ED's and BG's will be needed in order to accumulate a representative sample. Some of the ED/BG's will be in each of several categories, with income probably being the most relevant stratifier. Appropriate weighting factors may be derived to apply to the results to extrapolate to the whole region. STF-3 data, including income data, is available at the BG or ED level. At that level, data is subject to a noticeable but not fatal amount of sampling error, and is also subject to a great deal of suppression of data. The broad range of information available from STF-3 and the availability of income data, makes it a valuable source however.

STF-1 data has the advantage of being complete count data. It offers freedom from sampling error, at the cost of providing no income data. The value of owner occupied residential structures, according to the opinion of the census respondent, or the contract rent, for renter occupied dwellings, is reported by STF-1, and may serve as a rough surrogate for income.

The primary value of STF-1 data is that selected STF-1 data is available at the block level, and thus may be used in constructing a sampling scheme involving households selected from blocks, which taken in aggregate, are representative of the area being studied. Blocks may be selected at random, for example, and certain blocks which are unsuitable, for instance blocks consisting largely of apartments, may be discarded. Individual households may be chosen for study according to a random or systematic scheme. It would be advisable, however, if sampling is done at the household level, to collect demographic data directly from the sample households.

4.4 Data for Facility Planning

4.4.1 Data for Municipalities or Counties

The purpose of all of these exercises is presumably to plan for waste management facilities, including material recovery facilities, waste to energy incinerators, and landfills. Once

reasonable estimates of generation rates and composition are obtained, it will be desired to apply them to proposed facility service areas in order to estimate the amount and composition of waste that will be generated.

The most easily applied means of using data for waste projections would be to have census population data and employment by SIC code available at the municipal level. Facility service areas will probably consist of a collection of municipalities. Data for the entire service area may be obtained by accumulating the data for each of the municipalities. Generation rates may be applied to the accumulated data.

Alternatively, generation rates may be applied to the data at the municipal level, and waste generation projections accumulated. The reason for the possibility of applying generation rates prior to accumulation would be the potential differences in generation between rural and urban areas, say, or between upper and lower income areas.

4.4.2 Use of a Computer Database

A computer database should be used to store and manipulate data for facility planning. One important reason for using a computer database is the ease with which data may be combined and recombined in the course of planning and analysis.

Census data from the summary tape files may be extracted from the tapes into custom files on a mainframe computer, and the files downloaded to microcomputer diskettes. The preferred format for microcomputer diskette would be double sided double density IBM MSDOS format, which has become the de-facto standard for microcomputing in the business world. The files should be all ASCII files, and will be readable, at a minimum, by BASIC and dBase II and dBase III, and Lotus 1-2-3. Most microcomputer database programs will read ASCII files.

The reading of the summary tape files will require the services of a person or organization with access to the tape files, access to a suitable mainframe computer, and expertise in reading the tapes. The usual means of access to the tapes is through the use of a Census Bureau software package known as CENSPAC. CENSPAC is a vile language which is difficult to understand and quirky to use, but it is useful for reading the tapes and creating files for use by other packages. There will very likely be competent CENSPAC programmers available via a State Data Center, or at a major university.

With custom files created on a mainframe, the files should be downloaded by modem to a microcomputer. If a person with experience in this process is available it will go smoothly.

Careful planning may be needed to ensure that data will fit on the limited capacity of the floppy diskettes. Planning of the

file structure may be necessary in order to meet the requirements of the programing languages used on the microcomputer. For example, Microsoft Basic, which is virtually a de-facto standard, can handle string variables up to 255 characters long. If information for each unit of geography is represented by a string of no more than 255 characters, processing may be more convenient.

A preliminary rough cut at estimating the storage required indicates that 500 municipalities, with 37 data fields, each field requiring 7 characters, would demand a total of 129,500 characters, not counting carriage returns. That would occupy only 36% of the available 360K capacity of an IBM diskette. It is possible, however, that consideration of planning needs in and around large urban areas, such as Boston, will require the addition of tract data for certain areas. Such additions could increase the total amount of data to be stored on a diskette. Nevertheless, it would appear that a useful set of census data could be created that could be very practically manipulated on a microcomputer.

An alternative to downloading census data from summary tape files is to purchase pre-prepared diskettes. For example, the City-County Data Book is available on diskettes from the Census Bureau. There are also a number of private firms offering data on diskette. Data offered by private firms tends to be oriented toward retail market research. This data may be useful for planning recycling and solid waste facilities. If the prepackaged data does not suffice, most firms offer custom diskette preparation, albeit at a higher price.

It is highly likely that special purpose subsets of data would be created for particular analyses. The most obvious example would be to create a dataset containing only non-institutional population, for the purpose of quickly and easily calculating the population of proposed service areas. Creation of specialized subsets of data could be done either on a mainframe computer, or a microcomputer. The choice will depend on the balance between available budget for mainframe timesharing and available programmer time for the mainframe, versus the essentially free time on the microcomputer and the adeptness of the users.

Recommended microcomputer software for data manipulation includes Microsoft Basic, and either dBase II or dBase III. Microsoft Basic is useful for file manipulations, such as extracting portions of each record and preparing a second file for input to dBase. DBase II and dBase III are "data base management" packages, which allow the extraction of records meeting certain criteria, calculation of derived fields such as percentages, and accumulation of totals from many records.

There are many data base management packages available for microcomputers, and there are no doubt other packages that would be suitable. The advantages of the dBase software are 1) a

powerful procedural language is available that allows maximum flexibility in manipulating data, 2) there are many individuals who are familiar with the packages because dBase II has been in use for a long time, and dBase III is sufficiently similar for skills transfer to be easy. Lotus 1-2-3 offers somewhat limited database capabilities, but may prove useful because of its superb spreadsheet.

Employment data, by SIC code, almost certainly exists on computer tape. The availability of that data for processing by persons outside of the immediate agency preparing the data is probably not as well institutionalized as is the case with Census data. If necessary, data may be hand entered into microcomputer files. However, it would be preferable to arrange to download selected data, because the data entry process is both tedious and error prone.

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